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CONTRIBUTIONS FROM THE ANATOMICAL LABORATORY OF THE UNIVERSITY OF WISCONSIN

BY

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INTRODUCTION.

The University of Wisconsin requires that each student shall, before graduation, write a thesis on some subject selected either by himself or the professor under whom the work is to be done.

The subjects of the following four papers were suggested to the students, named below, of the class of 1898. The results of their work were so satisfactory that I have quite largely incorporated them in the present Bulletin.

The description of the vascular system of *Necturus maculatus* I hope will be of assistance to those who use the animals in their laboratories. For several years I have used them in my course in vertebrate anatomy, and feeling the need of some detailed description of the blood-vessels, I kept notes on each animal used. The results, as embodied in the present paper, represent the dissection of over 200 animals and cover four years' work.

Those who have used *Necturus* in laboratory courses know how variable they are. The text and diagrams represent the most constant type. I regret that I have not been able to consult what is practically the only work on *Necturus* that is known to me, "Ontleed en dierkundige bydragen tot de Kennis van Menobranchus, den Proteus der Meeren van Noord-Amerika." J. van der Hoeven. Leiden, 1867.

I should be very glad to receive any corrections which other workers find desirable on comparison with their own notes; also suggestions on the nomenclature, which I realize is faulty in some places.

The following gentlemen of the class of '98 have assisted in the preparation of these papers:

H. W. Ochsner: The Lung of *Necturus maculatus.*

A. Sauthoff, J. H. Van Vorhis: The Vascular System of *Necturus maculatus.*

C. A. Squire: The Brain of *Necturus maculatus.*

A. W. Meyer. The Epithelium of the Peritoneal Cavity of the Cat.

These papers by no means represent all the worthy work done in the Laboratory. Some of the subjects are being worked out gradually; a few points this year, a few more the next and so on until at last they can be gathered up into a complete paper.

THE LUNG OF *Necturus maculatus*.

The lungs of *Necturus* consist of two long, narrow, transparent membranous sacs, which extend backwards into the abdominal cavity dorsal to the other viscera. Their outer surface is perfectly smooth and is covered by a layer of the peritoneum lining the pleuro-peritoneal cavity, thus forming a mesentery which attaches them to the dorsal body wall along almost their entire length. In a full grown specimen, whose lung is from 100–125 mm long when distended, less than 25 mm is free. Each lung is a perfectly simple sac, no septa being developed, and their cavities open into the pharynx through a common membranous tube running in the dorsal wall of the pericardial cavity. This tube represents the trachea of higher vertebrates.

The epithelium, which forms the outermost layer (serous layer) of the lung of *Necturus*, varies in size and outline in the various parts of the lung, as may be seen from Pl. 3, figs. 1, 2; Pl. 4, fig. 3. Between the large blood-vessels and especially in the anterior part of the lung, the epithelium is of the common type, as shown in Pl. 3, fig. 1. It consists of large, thin, irregular cells with comparatively smooth boundaries. The nuclei of these cells do not seem to occupy any one characteristic position, but are found in all parts of the cell. Toward the posterior end and along the sides of the blood-vessels we find the cells taking on a longer and a narrower shape, making them irregularly oblong, as shown in Pl. 3, fig. 2. The nearer we approach the tips of the lungs, the narrower and longer do the cells become. Between the lateral branches of the blood-vessels we very often find whorls of cells, centering around a rather large irregular one. Covering the blood-vessels and lymphatics we have an entirely different type of epithelial cell, as shown in Pl. 4, fig. 3. The cells are often extremely long and always have very jagged edges, more so than the figure indicates. Between these types we find all gradations, though the last type passes over into the others very abruptly, as a rule.

In all my specimens I was not able to see a single spot or orifice which I could construe to be a stomata. It is true that there were some small spots in some of the preparations, but they could always be traced to over distention, tearing, or drying of the lung. Indeed, they could be produced in any quantity by just such procedures.

Along the inner side of the lung, near the pulmonary vein, pigment cells are often found which present many bizarre shapes.

THE PULMONARY EPITHELIUM.

If a *Necturus* be killed by cutting off its head and one of its lungs be removed, cut open and spread out on a slide in salt solution, and its inner surface examined under a medium power, it will be seen that the epithelium is apparently collected into groups or islands of cells which are surrounded by clear spaces. This arrangement coincides with that given by Schulze, Schmidt and Ranvier for the frog, and by Williams and Stirling for the newt.

Schulze describes the relation between the capillaries and the epithelium of the lung of Reptiles and Amphibians as follows:

> "All respiratory capillaries are attached to the alveolar wall only on one side. They would project freely, with their greatest circumference, into the air cavity, if they were not completely covered by a continuous plate-like epithelium. The large polygonal cells of this alveolar epithelium, meeting accurately at their sides, cover the surface of the capillaries, turned toward the air cavity, with thin, transparent, plate-like expansions and send plug-like continuations, generally the nucleus with some surrounding protoplasm, into the capillary network and indeed so far down that they reach the connective tissue stroma of the alveolar wall, and so completely fill the spaces of the capillary network. These plug-like continuations, harboring

> the nucleus and protoplasm of every cell, are usually found in the corners of the single cells, so that several plugs lie together and are found in a single capillary mesh. Still, many cells are also found which bear their granular continuations nearer the middle and completely fill a capillary mesh."

Williams says:

> "The epithelial scales which cover the capillary areas of the lung of the newt (parts which coincide with air-cells of the mammalian lung) lose not only the external appendages (cilia), but also their internal parts (nuclei and granules). This successive reduction leaves nothing but a hyaline involucrum enclosing a pellucid fluid."

Stirling also investigated the lung of the newt and says:

> "The arrangement of these cells is curious. They lie in groups, and the large nuclei occupy the small spaces left between the blood-capillary network, whilst the thin plates of each cell cover the capillary wall. The result of this arrangement is that the air in the lung is separated from the blood-stream merely by the cell plate of these cells and the squames which form the capillary wall."

If now the remaining lung be carefully removed and stained by means of nitrate of silver, the outline of the cells and their nuclei will be brought into view. Pl. 4, fig. 4, shows the outline of the cells, also that of the islands in which the nuclei and protoplasmic part of the cells are situated. Pl. 5, fig. 5, shows the relation of the nuclei and protoplasm to the cell boundaries in a case where several nuclei are found in a single mesh of the capillary network. Sometimes we find a single nucleus filling the whole mesh and lying near the center of the cell, as shown in Pl. 5, fig. 6. Sometimes we find the cell boundaries apparently cutting through a nucleus, as we see them doing in a few instances in Pl. 5, fig. 7. This is merely a condition due to the over-lapping of one cell by another, as was shown by Schmidt in the case of the frog. A projection of the relation of the nucleus to the boundary lines is shown in Pl. 5, fig. 8.

To demonstrate the presence of cilia the animals were killed by pithing; the lung was then removed and cut open along both the artery and the vein. The cilia were seen to better advantage at the edges of the preparation than on the surface. Ciliated epithelial cells were found over both the artery and vein, down to the apex of the lung, while a few were also found between them. This is not the case in the newt according to Stirling, the ciliated epithelium being found only over the pulmonary vein and its principal branches, while a plexus of capillaries lies over the artery. Williams, in contradistinction to Stirling, figures the ciliated epithelium over both the artery and vein of the newt. In *Necturus* I found a plexus of capillaries, as well as the ciliated epithelium over both artery and vein.

THE ELASTIC FIBERS.

The elastic fibers of the lung of *Necturus* form an exceedingly complex network, as shown in Pl. 6, fig. 9. The fibers are of two types, the coarser ones being nearer the surface, and forming wider meshes than the finer and deeper ones. They also run more generally in a direction parallel to the long axis of the lung. The meshes of the fine fibers are exceedingly intricate, especially around the blood-vessels. Stirling describes the elastic fibers as forming a layer lying between the endothelium and the layer of smooth muscle, but this cannot be said of the lung of *Necturus.* Fibers are found scattered throughout the walls of the lungs. Pl. 7, figs. 11, 12, show longitudinal and cross sections of the lung of *Necturus* taken near blood-vessels which show the fibers as dots or lines, according as they are cut transversely or more or less longitudinally.

THE MUSCLE FIBERS.

The muscle fibers are of the involuntary type and run principally in a circular direction, thus forming a tubular foundation for the lung. The nuclei of the fibers are shown in Pl. 7, figs. 11, 12; Pl. 8, figs. 13, 14. At the tip of the lung the fibers form an intricate network, running in all directions.

Stirling mentions a difference in position of the vein and artery with reference to the layer of muscle fibers, the artery lying internal to this layer, while the vein lies externally to it.

This does not hold true for the lung of *Necturus*, since both the artery and the vein lie superficially, the greater part of the muscle fibers lying internal to them. Pl. 8, figs. 11, 12, shows the relation between the blood-vessels and the muscular fibers. It will be noted that the relation is the same in both the artery and vein.

THE NERVE FIBERS.

The distribution of the nerves in the lung is shown in Pl. 6, fig. 10, and Pl. 8, fig. 15. Contrary to the usual opinion, we do not find the main branches along the blood-vessels, but rather between them. To be sure, there are nerve trunks lying over the blood-vessels, yet they are not so large as those forming the elongated meshwork between them. The anastomoses between the trunks are quite numerous, increasing as they diminish in size until we come down to the ultimate fibers.

This distribution is contrary to that found by Stirling in the lung of the newt. He says:

> "The nerves enter the lung in three or four main strands at its base. These strands are of unequal thickness, i. e., a varying number of nerve-fibers enter into their composition. At once they proceed towards the pulmonary vein, which they follow very closely in their distribution. They form a plexus along the course of the vein. Only a few non-medullated nerve-fibers pass on to the pulmonary artery. The nerve-strands lie outside the muscular coat, and as they pass onwards in the pulmonary walls they give off branches right and left. A large number of multipolar nerve-cells exist in the course of the nerve-strands, and they are especially numerous where a branch is given off."

Both medullated and non-medullated fibers are found in the main trunks. From this main network we get a second network with fewer fibers in a branch, but still containing both kinds of fibers. From this secondary network we have a fine network of non-medullated fibers given off which breaks up into the ultimate fibrils. These last I did not try to follow out to their endings. Along the course of the fibers, as well as the trunks, nerve-cells are present, and my observations in *Necturus* coincide, except in the connections between the fibers and cells which I did not investigate, with those of Stirling in the newt. He says:

> "A large number of nerve cells are found along the whole course of these mixed nerve strands and occur singly or in groups, and are usually most numerous where branches are given off.
>
> "They are not confined to the main trunks, however, but recur singly or in small groups in the larger nerve branches. Sometimes the cells lie singly between the sheath of the nerve and the nerve fibers, whilst others lie crushed up as it were between the nerve fibers. As already remarked, they are most numerous where a nerve twig is given off from the main mixed strand. In these small aggregations of nerve cells it is easy to trace the course of a medullated fiber sweeping clear through the mass, and forming no connections with the cells, whilst, occasionally, one may see a connection between a nerve cell process and one of the non-medullated fibers. The shape of the nerve cells seems to vary considerably; some appear to be bipolar, whilst others are polygonal and have several processes, one or more of which may become continuous with a non-medullated fiber. Each cell contains a relatively large nucleus usually placed eccentrically, and the body of the cell may or may not be enclosed in a capsule. Other nucleated masses of protoplasm devoid of processes lie amongst the nerve fibers, and it is not clear what is their exact nature. Perhaps they may represent developing nerve cells."

TECHNIQUE.

The specimens were killed by chloroform, although some were used that had been dead for a few hours, and those used for the work on the epithelium were killed by pithing. The lungs were removed by opening the body cavity at the left side of the median ventral line and then cutting through the ventral mesentery, which allowed me to throw back the flap of the body-wall, thus exposing the whole of the viscera to view. The lungs were carefully blown up with a syringe introduced through the mouth, into the glottis. This made the lungs very prominent and it was a comparatively simple matter to cut through the fold of peritoneum, which attaches the lung to the body-wall. Care was exercised, in handling the lungs, not to puncture them, as their walls were very thin. Threads were passed around each of the lungs near their union at the anterior end of the liver and then they were cut off and at once put into the fixing fluid or into the stain as the procedure necessitated. As the lung was kept distended by this method it allowed me to handle it without touching the surfaces and at the same time produced a uniformly distended and perfectly smooth surface. On account of the great amount of blood present in the lungs, it was found necessary to remove it in some manner so as to be able to see the finer structures, especially with a high power. This was done by washing out the blood with normal salt solution, injecting it into the main artery.

For the study of the peritoneal covering and of the epithelium of the lung, the usual methods with nitrate of silver were used. An interesting point was brought out while investigating the epithelium, viz., that while on all ordinary serous membranes Dekhuysen's method had given the most satisfactory results, in *Necturus* it proved to be exceedingly unsatisfactory. This was probably due to some action of the nitric acid on the peculiar viscid secretion which covered the lungs; for, when after many failures the simple aqueous solution was used, each cell appeared bounded by clear and sharply defined lines.

For elastic fibers Hoehl's modification of Unna's orcein stain for the skin was used; it gave uniform and very satisfactory results. For the nerves methylene blue was use with varying success.

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PLATE 3.

DESCRIPTION OF PLATE 3.

LUNG OF *Necturus maculatus.*

Fig. 1. Epithelium between the large blood-vessels. × 165.

Fig. 2. Epithelium near the large blood-vessels and end of lung. × 165.

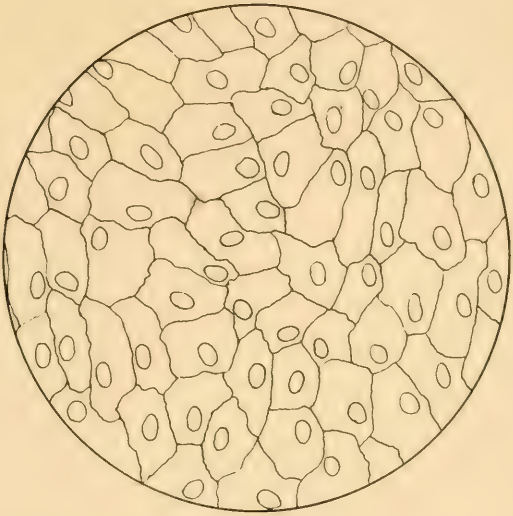

fig. 1.

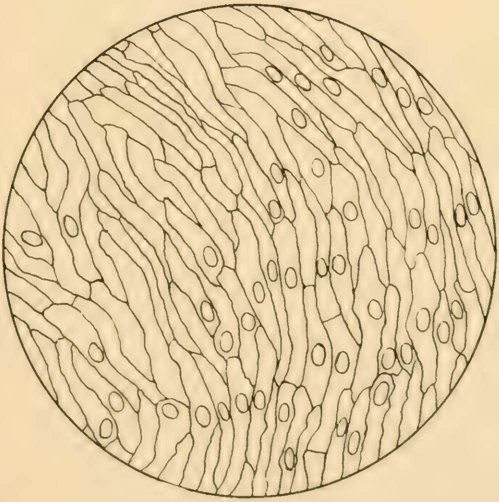

fig. 2.

PLATE 4.

DESCRIPTION OF PLATE 4.

LUNG OF *Necturus maculatus.*

Fig. 3. Epithelium over the blood-vessels and lymphatics. × 165.

Fig. 4. Epithelium within the lung showing outline of cells and islands. × 250.

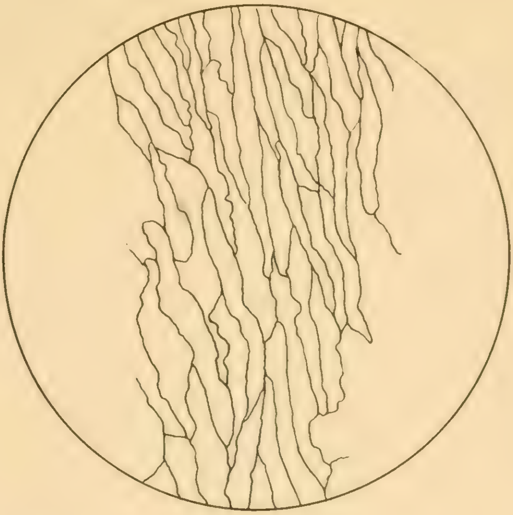

fig. 3.

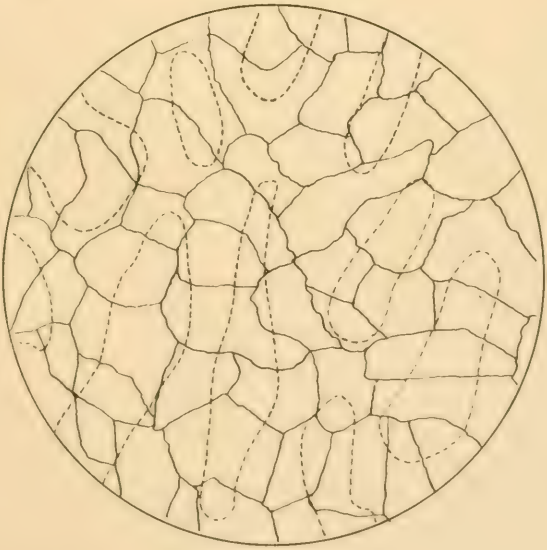

fig. 4.

PLATE 5.

DESCRIPTION OF PLATE 5.

LUNG OF *Necturus maculatus.*

Fig. 5. Relation of nuclei and protoplasm to group of cells in an island. × 350.

Fig. 6. A single cell forming an island. × 250.

Fig. 7. Cell boundaries crossing over nuclei of neighboring cells. × 250.

Fig. 8. Projection drawing of two cells from figure 7, showing relation of cell boundaries to nucleus and to two underlying capillaries. × 250.

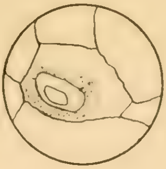

fig 6

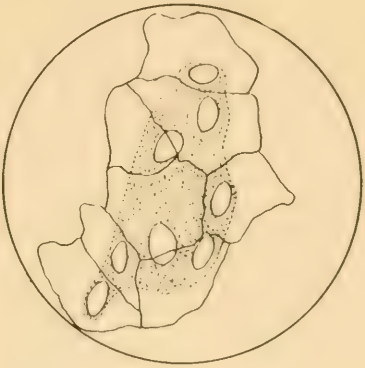

fig.7

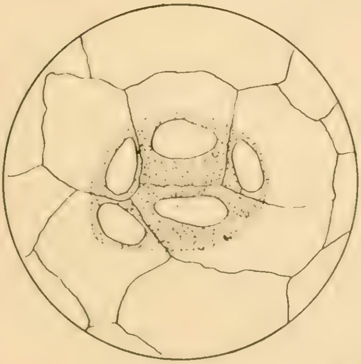

fig. 5.

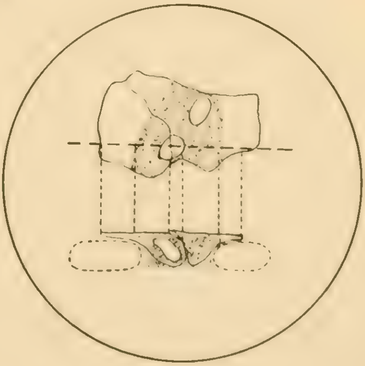

fig. 8.

PLATE 6.

DESCRIPTION OF PLATE 6.

LUNG OF *Necturus maculatus*.

Fig. 9. Surface view of elastic fibers over the pulmonary artery. Orcein staining. × 400.

Fig. 10. The finer network of nerve fibers, showing medullated and non-medullated fibers and nerve cells. Methylene blue. × 75.

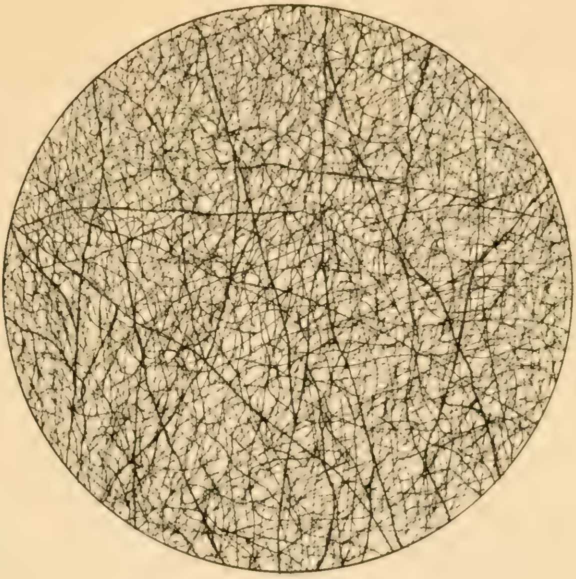

fig. 9.

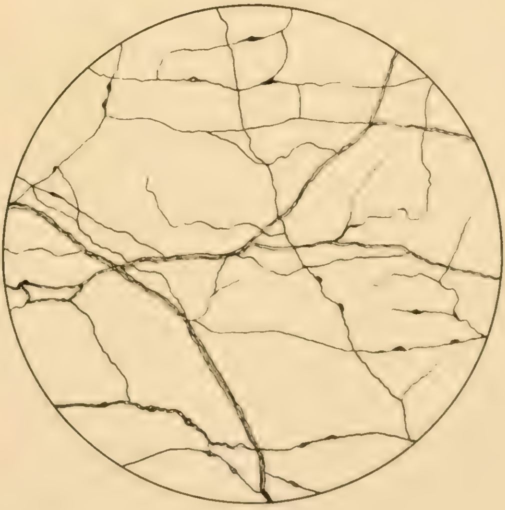

fig. 10.

PLATE 7.

DESCRIPTION OF PLATE 7.

LUNG OF *Necturus maculatus.*

Fig. 11. Elastic fibers and muscle nuclei in a longitudinal section of lung. Orcein staining. × 400.

Fig. 12. A transection of lung. Same preparation as figure 11. × 400.

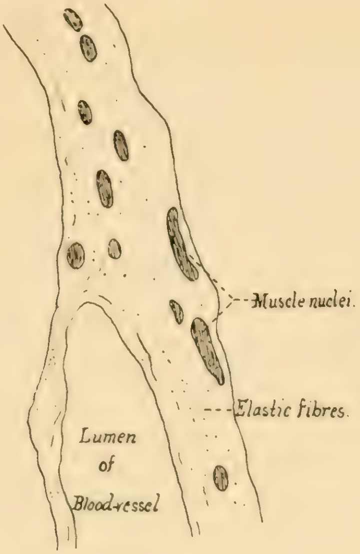
Muscle nuclei.
Elastic fibres.
Lumen of Blood-vessel

fig. 11.

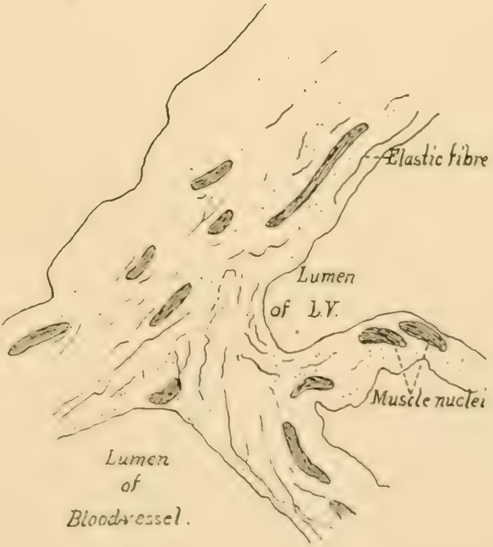
Elastic fibre
Lumen of L.V.
Muscle nuclei
Lumen of Blood-vessel.

fig. 12.

Plate 8.

Description of Plate 8.

Lung of *Necturus maculatus.*

Figs. 13 and 14. These sections show the relative thickness of the layer of muscle fibers, both internal and external to the artery and vein. Note the superficial situation of both vessels. × 40.

Fig. 15. The distribution of the main nerve trunks. × 3.

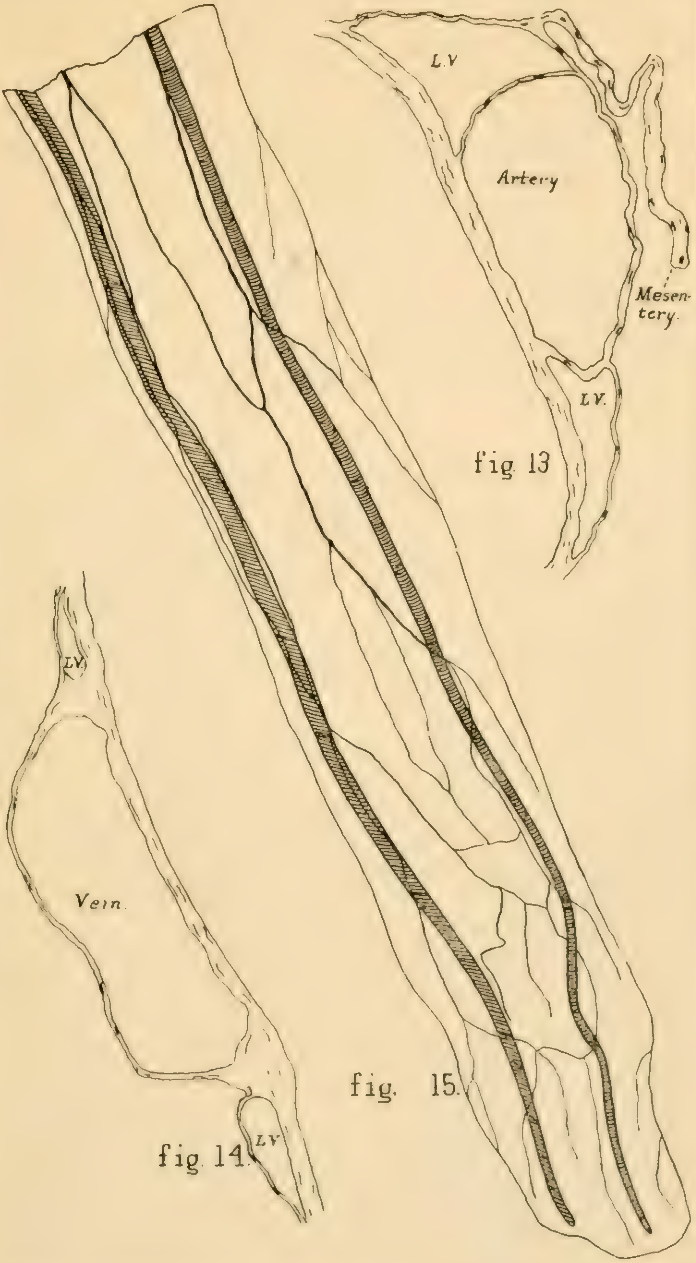

fig. 13

fig. 14.

fig. 15.

THE VASCULAR SYSTEM OF *Necturus maculatus.*

THE ARTERIES.

For convenience of description the ventral aorta and its branches will be considered with the arteries although it contains venous blood.

From both sides of the anterior extremity of the TRUNCUS ARTERIOSUS, Tr. Pl. 9, and fig. 1, Pl. 10, arise two vessels, a smaller anterior and a larger posterior. For a distance of about 5 mm they appear as a single vessel, being separated merely by a septum. The anterior, THE FIRST AFFERENT BRANCHIAL ARTERY, A. B.–1, Pl. 9, and fig. 1, Pl. 10, runs out almost at right angles to the truncus, to the first branchial cartilage, along the postero-ventral edge of which it continues to the gill. In the gill it runs along its ventral edge, giving rise to numerous fine branches which subdivide and form a loop, with a capillary network between, in each tuft. The posterior larger vessel also runs out nearly at a right angle to the truncus parallel to the first afferent vessel, then makes a sharp turn caudal, continuing between the two posterior branchial cartilages. About 5 mm posterior to the turn it divides into two branches, the SECOND and THIRD AFFERENT BRANCHIAL ARTERIES, A. B.–II., A. B. –III., Pl. 9, and fig. 1, Pl. 10. Each runs along the corresponding branchial cartilage into the gill, where it breaks up in a manner similar to the first.

The EFFERENT BRANCHIAL ARTERIES arise by numerous radicles formed by the capillaries of the gill tufts uniting along the dorsal edge of the gill to form a common vessel. Just at the point where the FIRST and SECOND EFFERENT BRANCHIAL AR-

TERIES, E. B.–I., E. B.–II.. Pl. 9, and fig. 1, Pl. 10, leave the gill, each gives off a branch which crosses the proximal edge of the gill. The branch arising from the first efferent artery forms the EXTERNAL CAROTID, E. C., Pl. 9, and fig. 1, Pl. 10, while the branch arising from the second efferent artery goes to the second afferent branchial artery, E. B. a., Pl. 9, and fig. 1, Pl. 10. The SECOND and THIRD EFFERENT BRANCHIAL ARTERIES unite at the posterior edge of the second branchial cartilage. The vessel thus formed, C. V., Pl. 9, and fig. 1, Pl. 10, and the first efferent branchial artery are united by a short vessel, A. B., Pl. 9, and fig. 1, Pl. 10, as soon as they enter the buccal cavity, along the dorsal side of which they run. The first efferent branchial artery, after giving off the above connecting branch, A. B., makes a bend and runs directly cephalad as the INTERNAL CAROTID, I. C., Pl. 9, and fig. 1, Pl. 10. The vessel formed by the union of the second and third efferent arteries, after giving off the pulmonary artery, P., Pl. 9, and fig. 1, Pl. 10, is continued as one of the AORTIC ROOTS, R. A., Pl. 9, and fig. 1, Pl. 10.

The INTERNAL CAROTID, I. C., Pl. 9, arises from the first efferent branchial artery at the point where the anastomosing branch is given off to the conjoined second and third efferent arteries. It runs along the medio-ventral edge of the masseter muscle and the ventral surface of the parasphenoid bone making two convex and one concave turn towards the outside. It pierces the parasphenoid opposite the first branchial cartilage, continues along its dorsal surface for a short distance, about 8 mm, pierces it a second time, and, running along its ventral surface, ends in the premaxilla.

At a point just anterior to the first gill the internal carotid gives off several branches. They pierce the parasphenoid bone and emerge anterior to the pterygoid. The most posterior of these branches, the INTERNAL INFERIOR MAXILLARY, I. I. M., Pl. 9, runs under the tympanicum to the ramus of the lower jaw, where it gives off a branch to the digastric and mylohyoid muscles, a branch to the branchial cartilages, and then continues along the internal side of the ramus of the lower jaw, giving off a branch to the lip. The second branch, the EXTERNAL INFERIOR MAXILLARY, E. I. M., Pl. 9, runs along the anterior side of the pterygoid and is distributed to the outer surface of the ramus of the lower jaw. A third branch, the ORBITO-NASAL, O. N., Pl. 9, runs along the lower border of the temporal muscle between it and the masseter muscle; passing around the dorso-median side of the eye it gives off branches to the muscles of the orbit, and then goes to the nasal fossa, where it divides into two branches, one on each side. Two small branches pass to the temporal muscle. Another branch of considerable size is the OPHTHALMIC, Oph., Pl. 9, which arises in common with the other branches of the internal carotid and runs nearly parallel with its distal part to be distributed to the eye. Sometimes the ophthalmic sends branches to the nasal capsule.

Just as the internal carotid pierces the parasphenoid it gives off a branch at nearly a right angle, the CEREBRAL CAROTID, C. C., Pl. 9, which passes to the ventral side of the brain where it divides into an anterior and a posterior branch. The anterior continues along the ventral surface of the cerebral hemisphere of the same side, ending in a number of fine branches. The posterior branch runs diagonally caudad and unites with its fellow from the other side to form the BASILAR ARTERY, Bs., Pl. 9, and then runs along the ventral side of the medulla, giving off branches at right angles to its course. The two largest of these, Au., Pl. 9, pass one on either side to the ear.

The VERTEBRAL ARTERY, Vert., Pl. 9, arises from the root of the aorta, runs cephalad to the parasphenoid, where it divides into two branches, one running towards the median plane, the other away from the median plane. The latter again divides into three small branches, a posterior and a lateral branch going to the roof of the mouth and an anterior branch to the side of the medulla. The former branch runs along the spinal column dorsal to the lateral processes.

The PULMONARY ARTERY, P., Pl. 9, and fig. 1, Pl. 10, arises from the third efferent branchial artery between the point where the second efferent artery joins it and where the anastomosing branch from the first efferent enters. It gives off a few small branches to the shoulder, one, Ps., Pl. 9, going to the muscles of the scapula and one, Pb., Pl. 9, to the cucullaris muscle; from here it continues along the ventral surface of the buccal cavity giving off one or two branches to it, a branch to the œsophagus, P. oe., Pl. 9, and then proceeds along the dorsal side of the lung giving off short branches at right angles to its course.

The External Carotid Artery, E. C., Pl. 9, and fig. 1, Pl. 10, arises from the first efferent branchial; it also receives a number of small anastomosing branches from the first afferent branchial artery which accompany it as far as the sternohyoid muscle, which it supplies with a branch. From here it continues cephalad along the medio-dorsal surface of the digastric muscle closely applied to the hyoid arch, giving off a branch to the geniohyoid and mylohyoid muscles and then anastomoses with its fellow from the other side at the insertion of the digastric muscle into the lower jaw.

The Dorsal Aorta, A. O., Pl. 9, is formed by the union of the two aortic roots and runs along the ventral surface of the vertebral column. It is the main trunk of the arterial system and gives off numerous branches as it passes backwards through the abdominal cavity.

The Subclavian, Sbc., Pl. 9, and fig. 2, Pl. 10, arises from the aorta about 5 mm posterior to the union of the aortic roots, runs outward between the external oblique and erector spinae muscles, makes a slight turn dorsad and continues along the ventral surface of the scapula. Near the glenoid fossa the continuation of the subclavian, now called the Axillary Artery, gives off a branch which may be called the Thyroid Axis, T. A., fig. 2, Pl. 10. This almost immediately gives off a branch, Ta., fig. 2, Pl. 10, which enters the anconeus muscle and breaks up into three smaller branches. The most anterior, T. a. c., fig. 2, Pl. 10, passes between the anconeus and the humero antibrachialis inferior muscles across the head of the ulna, along the surface of the extensor digitorum communis to the first digit. The middle branch, T. a. b., fig. 2, Pl. 10, runs along between the head of the radius and the ulna to the last digit. The smallest and most posterior branch, T. a. a., fig. 2, Pl. 10, goes to the anconeus. The main portion of the thyroid axis, Tb., fig. 2, Pl. 10, runs across the head of the humerus into the procoro humeralis giving off several branches which supply this muscle, the cucullaris and the antibrachialis inferior. The latissimus dorsi may receive its blood supply from this artery or from T. a. a.

The CUTANEOUS ARTERY, Cu., Pl. 9, and fig. 2, Pl. 10, arises from the axillary and runs across the ventral surface of the coracoid; a little posterior to the glenoid fossa it gives off two branches, one, Ca., fig. 2, Pl. 10, accompanies the brachialis around the upper part of the shaft of the humerus and continues between the coraco branchialis longus and the humero antibrachialis inferior. Sometimes this branch arises directly from the axillary artery. The other branch, Cu. a., fig. 2, Pl. 10, of the cutaneous goes to the pectoral muscles, while the cutaneous itself, Cu., Pl. 9, passing candad, pierces the body wall and runs along its inner surface external to the linea alba anastomosing with the intercostals and the epigastric.

The continuation of the axillary, the BRACHIAL ARTERY, Br., fig. 2, Pl. 10, passes around the upper part of the shaft of the humerus to its anterior side, running between the extensor carpi radialis and ulnaris muscles; passing between the radius and ulna it crosses to the outside of the forearm ventral to the extensor digitorum communis. Just proximal to the carpus the brachial gives off four branches; one, Br. a., fig. 2, Pl. 10, to the flexor carpi radialis, which is continued to the outside of the first digit; one, Br. b., fig. 2, Pl. 10, to the flexor carpi ulnaris, which continues to the fourth digit; one to the flexor digitorum communis and one to the extensor carpi ulnaris. The brachial is continued as the CUBITAL ARTERY, which runs between the cartilages of the carpus to the dorsal side of the hand, where it breaks up into three branches. The first of these goes to the adjacent sides of the first and second digits, the second goes to the adjacent sides of the second and third digits, the third goes to the adjacent sides of the third and fourth digits.

The next large artery arising from the dorsal aorta is the GASTRIC, G., Pl. 9. It runs candad to the stomach on which, a little anterior to the center, it divides into two branches, one going to the right side, the other to the left. Both branches subdivide to supply this organ and in addition to this the left branch gives off one or two branches to the spleen, Sp., Pl. 9.

The COELIACO-MESENTERIC, Coe. M., Pl. 9, arises from the dorsal aorta near the center of the abdominal cavity and runs out at right angles to the aorta through the pancreas, where it divides into three main branches. The first of these branches runs cephalad through the anterior lobe of the pancreas dividing into two smaller branches, one containing anterior, as the SPLENIC, Sp′., Pl. 9, to supply the spleen, the other runs out at nearly a right-angle to the stomach; this is the CORONARY, Cor., Pl. 9. The second branch is the HEPATIC, Hp., Pl. 9, which supplies the liver and the gall bladder. The third branch goes to the intestine.

The INFERIOR MESENTERIC ARTERIES, I. M., Pl. 9, sometimes as many as twenty in number, arise from the aorta at varying intervals and run to the intestine, dividing, and as a rule, anastomosing before they reach it, forming a sort of discontinuous vessel along the attached border of the intestine. From this, short semi-circular arteries arise which pass to the wall of the intestine.

In the male, nine to eleven SPERMATIC ARTERIES, Spr., Pl. 9. arise on each side from the dorsal aorta and enter the testis. In the female numerous minute arteries go to the fallopian tubes and ovaries. The kidneys receive also a variable number of RENAL ARTERIES, K., Pl. 9, which arise from the aorta.

Throughout the entire course of the aorta short vessels arise at regular intervals from its dorsal side, corresponding in number to the vertebrae; these run dorsad at right angles to the aorta and divide into two branches, one for each side. Each branch runs outwards between the oblique muscles, to which they give off small branches, and at their distal end anastomose with the cutaneous and epigastric. The name INTERCOSTAL ARTERIES, Icls., Pl. 9, may be given to these vessels. Between the intercostals, dorsal to the lateral processes of the vertebrae, lie anastomosing branches, Anas., Pl. 9, which are continuous with the vertebral.

The ILIAC ARTERY, Il., Pl. 9, and fig. 3, Pl. 10, arises from the aorta just anterior to the posterior extremity. It runs outward and backward along the inner surface of the body wall until it reaches a point directly above the ischium, where it divides into three main branches. The most anterior, the EPIGASTRIC ARTERY, Epi., Pl. 9, and fig. 3, Pl. 10, runs cephalad and anastomoses with the cutaneous; it gives off a small branch, Epi. R., fig. 3, Pl. 10, to the rectus femoris and one to the body wall, Epi. B., fig. 3, Pl. 10. The middle and main branch is the FEMORAL ARTERY, Fr., Pl. 9, and fig. 3, Pl. 10, which directly continues the iliac. It crosses the ventral surface of the ischium and at its posterior border gives off a branch which immediately divides into three small branches. The most anterior of these, Fr. c., fig. 3, Pl. 10, runs around the head of the femur and continues between the rectus femoris and the sartorius; it breaks up in the flexor digitorum communis and sends a branch to the first digit. The second of these three branches, Fr. b., fig. 3, Pl. 10, runs under the rectus femoris and continues beneath the skin of the fore leg to the last digit. The third and most posterior branch, Fr. a., fig. 3, Pl. 10, goes to the sacro-plantaris muscle.

The femoral itself continues along the postero-dorsal surface of the upper half of the gracilis, crosses the femur diagonally to its anterior surface and continues between the gracilis and sartorius muscles. On the inner surface of the fore leg, between the tibia and fibula, it gives off several branches, one to the flexor tarsi tibialis, C. a., fig. 3, Pl. 10, which is continued to the first digit, one to the flexor tarsi fibularis, which is continued to the last digit, C. b., fig. 3, Pl. 10, one to the flexor and one to the extensor digitorum communis. The femoral then runs between the cartilages of the tarsus to the dorsal side of the foot, where it breaks up into three branches. The first of these goes to the adjacent sides of the first and second digits, the second to the adjacent sides of the second and third digits, and the third goes to the adjacent sides of the third and fourth digits.

The third branch of the iliac, the VESICAL ARTERY, Vs., Pl. 9, Vsc., fig. 3, Pl. 10, arises just before the iliac pierces the body wall. It runs along the ventral surface of the body wall to the bladder, where it, together with its fellow from the opposite side, gives off three branches to that organ. One of these branches sends a short twig to the posterior part of the intestine. The vesical then proceeds to the cloaca, Vs. Gl., fig. 3, Pl. 10, where it breaks up. At about the center of the vesical artery two branches are given off; one, Vs. I., fig. 3, Pl. 10, passes cephalad to the muscles on the ventral surface of the ilium, the other runs caudad to the cloaca, Vs. an., fig. 3, Pl. 10.

Just posterior to the anal gland the aorta enters the haemal arches of the candal vertebrae and continues to their end as the Caudal Aorta, Ca. A., Pl. 9, giving off branches to the muscles of the tail. At the anal gland the aorta gives off two branches, one, Gl., Pl. 9, on each side to the anal gland, and one, M., Pl. 9, to the muscles of the body wall.

THE VEINS.

The venous system of *Necturus* is exceedingly interesting, showing as it does points of resemblance to that of the Dipnoi on the one hand, and the higher Amphibia on the other. I would call special attention to the sinus between the postcaval vein and the *Sinus Venosus;* the communication between the posterior cardinals and the postcaval; the anastomosis between the posterior cardinals and the renal portal,—a condition which, it seems to me, is intermediate between that of *Protopterus annectens* and *Salamandra maculosa.* The constant presence of the anastomoses between the two sets of gastric veins is also quite conspicuous.

For convenience the venous system will be described under three heads:

1. RENAL PORTAL.
2. HEPATIC PORTAL.
3. SYSTEMIC VEINS.

In each case the description will be begun with the distal vessels and followed towards the heart.

RENAL PORTAL.

The Renal Portal system is formed by the bifurcation of the CAUDAL VEIN, C., Pl. 11. This arises at the end of the tail and runs in the haemal arches of the caudal vertebrae ventral to the caudal aorta. Just posterior to the cloaca the caudal vein bifurcates, each branch passing along the outer side of the corresponding kidney and giving off numerous vessels, VENAE ADVEHENTES, V. Adv., Pl. 11, into these organs. Into the renal portal open the veins from the posterior extremity.

Each of the four digits of the foot has two veins, one on either side; these two veins usually unite and form short and somewhat larger vessels, which join to form a still larger trunk on the dorsum of the foot. This latter vessel runs across the distal end of the extensor digitorum muscles near the proximal end of the digits. This transverse vein receives also a number of small vessels which come from the tarsus. From the outside of the foot this vein is continued towards the body as the POSTERIOR TIBIAL VEIN, Fbl., Pl. 11, which courses upwards, and near the knee joint it bends gradually and passes over the knee to the flexor surface of the leg. Above the knee it is continued as the FEMORAL VEIN (Sciatic?), Sci., Pl. 11; this passes over the hip joint and unites with the PELVIC VEIN, Pel., Pl. 11, about 10 mm from the point of union of the latter and the renal portal.

I am aware that this differs from the usual description of the veins in Amphibia. Most authors describe the femoral as dividing into two branches, a pelvic and iliac; but no such division could be made out in any of the specimens studied. The angle of union between the femoral and pelvic and the size of the pelvic precludes, it seems to me, such description.

Just below the knee the posterior tibial receives a branch which comes from the median side of the leg. Midway between the knee and the hip the femoral receives a considerable branch from the ventral side of the thigh and from about the knee joint. Just before the femoral joins the pelvic vein it receives two small branches; one from about the cloaca, the other from the anterior region of the thigh.

The two renal portals are connected by the Pelvic Veins, Pel., Pl. 11, which unite in the mid-ventral line of the body to form the ABDOMINAL VEIN, Abd., Pl. 11. The PELVIC VEINS, Pel., Pl. 11, unite with the renal portal near the middle of the kidney. From this point of union each pelvic vein runs along the inner side of the body wall until it is joined by the femoral; it also receives a number of small branches from the muscles of the back. After the femoral has joined it, the pelvic vein runs anteriorly towards the point of union with its fellow from the opposite side, where, as already mentioned, they form the ABDOMINAL VEIN, Abd., Pl. 11.

From its place of origin the abdominal vein runs through the ventral mesentery and the posterior part of the liver to join the hepatic portal. The abdominal vein receives close to the union of the two pelvic veins a small branch which comes from the anal gland and cloaca, A., Pl. 11. In its course through the ventral mesentery it receives the CYSTIC VEINS, Cys., Pl. 11; these are usually two in number. It also receives several small veins from the body walls. The abdominal vein enters the liver at the fissure in its posterior border. In its course through the liver it receives branches from the liver substance; the largest of these comes from the left side of the liver.

THE HEPATIC PORTAL.

The HEPATIC PORTAL, H. P., Pl. 11, is formed on the dorsal surface of the liver by the union of the mesenteric, gastric, splenic and abdominal veins. The MESENTERIC VEIN, Mes., Pl. 11, arises by from twelve to fifteen branches from the whole length of the intestine; occasionally at its distal end it receives a few small branches from about the cloaca. For the greater part of its course it is situated in the mesentery; the anterior portion, however, passes through the pancreas in order that it may reach the dorsal side of the liver. The anterior three branches from the intestine to the mesenteric vein are larger than the other branches and do not join it until after it has entered the pancreas.

The gastric vein arises from the posterior third of the stomach by two branches; one on the dorsal and one on the ventral side. These branches unite at the pylorus and form the GASTRIC VEIN, Gv., Pl. 11, which immediately enters that lobe of the pancreas which is closely applied to the intestine just posterior to the stomach. As it passes through the pancreas it receives small branches from the pancreas itself and the adjacent part of the intestine; it continues in the pancreas until it joins the mesenteric vein on the dorsal surface of the liver.

About 6 mm anterior to the junction of the mesenteric and gastric, the trunk thus formed is joined by the SPLENIC VEIN, Sp., Pl. 11. This vessel arises at the anterior end of the spleen, and in its course along the ventral surface of that organ receives many small branches from it. It is also joined by from two to four veins which bring blood from the dorsal portion of the anterior two-thirds of the stomach. The more anterior of these veins are smaller than those which come from the central region of the stomach. In two specimens a large vein was found running dorsally from the spleen, and, passing to the median side of the left lung, it joined the left posterior cardinal.

Just beyond the enlargement formed by the union of the mesenteric, gastric and splenic veins the ABDOMINAL VEIN, Abd., Pl. 11, usually joins the hepatic portal; in other cases it empties into the enlargement itself.

The HEPATIC PORTAL, H. P., Pl. 11, after being formed in the manner already described, runs anteriorly at the bottom of the fissure on the dorsal side of the liver. It becomes smaller and smaller, on account of the numerous branches which it gives off, and finally, at the anterior end of the liver, breaks up into small branches. About 20 mm from the anterior end of the liver a variable number of veins, two to four in number, coming from the antero-ventral portion of the stomach, G., Pl. 11, join the hepatic portal. The most posterior of these veins is the largest, and is mainly formed by a branch which can be traced posteriorly along the ventral side of the stomach to form an anastomosis with the ventral branch of the gastric vein, Gv., Pl. 11.

From the median line of the abdominal wall the hepatic portal receives from twelve to fifteen veins. Each of these veins is formed by two branches which, coming from either side in the septa of the abdominal muscles, unite at the mid-ventral line. These veins run from the body wall to the liver in the ventral mesentery, in which they often form an open network, each vessel being joined by a transverse branch, or they may unite so that not more than seven or eight veins enter the liver. Within the liver they join, as has been said, the branches of the hepatic portal.

All the blood which is brought to the liver by the hepatic portal and abdominal veins is collected by the Hepatic Veins, H., Pl. 11, which empty into the postcaval vein at different points along its course through the liver. The hepatic veins vary greatly in size and have no fixed point of entrance into the postcaval. Two of the hepatic veins are much larger than the others and have a fairly constant point of union with the postcaval. The larger of these two veins arises at the posterior end of the liver and joins the postcaval near the center of the liver. The other is not as constant in its course or place of origin; in the majority of the specimens examined it took its origin near the posterior border of the liver and ran along the left margin of the liver, receiving many small branches, and finally united with the postcaval at the anterior end of the liver. The first of these two hepatic veins is shown in Pl. 11, but for the sake of clearness the last is omitted.

SYSTEMIC VEINS.

The Posterior Vena Cava, or Postcaval Vein, P. C., Pl. 11, is the largest vein in the body; it runs anteriorly between the kidneys receiving through the Venae Reheventes, V. Rev., Pl. 11, the blood which has been brought to these organs by the venae advehentes, and a few veins from the muscles of the back. From the kidneys it is continued just ventral to the aorta until it is from 20 to 50 mm anterior to the posterior border of the liver; it then bends ventrally from the aorta and enters the liver somewhat to the left of the median line. In the liver it continues anteriorly until it reaches its anterior margin where it divides into the HEPATIC SINUS, H. S., Pl. 11, which, after being joined by the DUCTS OF CUVIER, D. C., Pl. 11, empties into the Sinus Venosus.

In the female the posterior vena cava receives on each side as it passes between the ovaries from fourteen to twenty OVARIAN VEINS, O., Pl. 11. The number differs not only in different specimens, but also on the different sides of the same specimens. These veins are small and very tortuous. Usually two or three form a small group and unite just before they enter the postcaval. They vary in length as well as in size; those from the center of the ovaries are about 10 mm long, while those from the ends are not more than 5 mm in length. The adjacent groups of veins are connected with each other by small cross branches near the ovaries.

In the male five, rarely four or six large, and several small, SPERMATIC VEINS run from each testis into the postcaval as it passes between them.

On the convex side of the bend where the posterior vena cava leaves the dorsal wall of the body cavity to enter the liver, it is joined by a vessel which branches like a Y, and connects it with each of the posterior cardinal veins, Y., Pl. 11.

The POSTERIOR CARDINAL VEINS, P. C., Pl. 11, arise near the central part of the body on each side of the aorta. They run anteriorly until near the Duct of Cuvier; here they bend laterally and empty into these vessels at their distal end. At their caudal end the posterior cardinals are connected with the renal portal by means of muscular branches which come from the back. Each muscular vessel in this region of the back, as soon as it penetrates the body wall divides into two branches, one of which passes anteriorly, the other posteriorly. These branches anastomose with each other and eventually with the posterior cardinal in front and the renal portal behind. The letters R. P., in Plate 11 are opposite the branches which form the anastomosis. This connection between the posterior cardinals and the renal portal is more marked in the female than in the male. Besides the muscular vessels taking part in the anastomosis there are others which join the posterior cardinal along nearly its entire length; these veins are about 6 mm apart and come from between the vertebrae. Each posterior cardinal communicates with the posterior vena cava on the convex side of the bend where it leaves the dorsal body wall. Sometimes the communicating vessels are separate and enter the postcaval near together. More often the veins from the posterior cardinals unite before they enter the postcaval as already described, V., Pl. 11.

The Fallopian Veins, F., Pl. 11, are small vessels which run in a wavy course along the ventral side of the anterior part of each fallopian tube. At the anterior end of each tube the vein joins the posterior cardinal of that side. Besides this principal vein there are numerous small vessels which pass from the walls of the fallopian tubes to the posterior cardinal veins, Z., Pl. 11. Opening into the fallopian vein, near its junction with the posterior cardinal, are two or more small branches which come from about the ostium abdominale of the oviducts.

Taking up now the veins that return the blood from the head, it will be seen that there are three: the internal jugular, the external jugular, and the lingual, on each side.

The Internal Jugular, Ji., Pl. 11, is formed principally by the union of two veins; one of these comes from the roof of the mouth, the other from the brain case, the upper part of the spinal column and the dorsal wall of the pharynx. From the place of union of these two branches, the internal jugular runs posteriorly to unite with the external jugular about 7 mm anterior to the junction of latter with the Duct of Cuvier.

The External Jugular, Je., Pl. 11, receives branches from the external parts of the head and from the ventral wall of the mouth. It is formed for the most part by the union of two veins. One of these, the Naso-Orbital Vein, N. Or., Pl. 11, runs across the masseter muscle, receiving branches from the antero-dorsal part of the head and from the eye. The other of these branches, the SUBMAXILLARY VEIN, Sbm., Pl. 11, is formed by branches from the antero-ventral wall of the oral cavity and the anterior portion of the lower jaw. The vessel thus formed passes along the ventral edge of the submaxillary bone, receiving in its course a number of branches from the ventral side of the head and from about the gill arches. About 4 mm posterior to the angle of the mouth this vessel unites with the naso-orbital to form the external jugular vein. From this point the external jugular vein runs posteriorly between the digastric and masseter muscles. In this part of its course the external jugular is just beneath, and closely applied to, the skin; it appears here as a sinus, the JUGULAR SINUS, J. S., Pl. 11, and receives numerous branches from the lateral and dorsal portions of the head; the largest of these branches is formed by the union of small branches from the temporal and masseter muscles. Just where the gills join the branchial cartilages this sinus runs ventrally for a short distance, then posteriorly and empties into the Duct of Cuvier external to the place where the subclavian vein enters. Just before making this last turn it is joined by the internal jugular.

The LINGUAL VEIN, Li., Pl. 11, is formed not only by branches from the tongue, but also from the digastric, the ceratohyoid and the geniohyoid muscles. From its origin it runs posteriorly along the gill arches until it reaches a point lateral to the Duct of Cuvier; it then turns towards the median line and joins the subclavian vein just before it empties into the Duct of Cuvier.

The LATERAL VEIN, L., Pl., 11, arise near the median region of the body wall and run anteriorly along the lateral line. Just external to the Duct of Cuvier it turns from its position beneath the skin and, passing towards the median line, joins the Duct of Cuvier external to the entrance of the posterior cardinal. The lateral veins are formed from branches which join them at right angles from the septa in the abdominal muscles. These branches may form an anastomosis with the veins which pass into the liver, along the ventral mesentery, from the body wall.

VEINS OF THE ARM.

Beginning at the distal end we find that each digit has two veins, one on each side; these two veins usually unite and form single vessels, these in turn form a transverse vein on the dorsal surface of the hand which passes across the extensor digitorum communis near the proximal end of the digits. Near the middle of the hand this vein turns toward the body and runs as the Radial Vein, Rdl., Pl. 11, as far as the elbow; here it is joined by a vein from the opposite side of the arm, the Ulnar Vein, W., Pl. 11. By the junction of the radial and ulnar veins there is formed the Brachial Vein, Hum., Pl. 11; this runs along the arm between the biceps and triceps muscles, and, passing over the glenoid fossa to the lateral side, continues to a point which is anterior and ventral to the Duct of Cuvier. Here it is joined by the lingual vein and empties directly into the Duct of Cuvier. Between the glenoid fossa and the Duct of Cuvier the vein is called the Subclavian, Sbc., Pl. 11. Just above the glenoid fossa the subclavian receives branches which come from the anterior part of the arm and from the muscles about the scapula.

PULMONARY VEINS.

The Pulmonary Veins, P., Pl. 11, are two in number, one from each lung. They run along the latero-ventral side of the lung and unite in the mid-line anterior to the union of the two lungs. From this point of union the now single pulmonary vein runs anteriorly towards the heart, and passing to the dorsal side of the two arms of the Hepatic Sinus it usually continues in the wall of the left arm of the sinus until it finally opens into the left atrium of the heart.

PLATE 9.

Description of Plate 9.

Vascular System of *Necturus maculatus*.

The arterial system of *Necturus maculatus;* diagram somewhat less than the natural size of the animal. The dissection was made from the ventral side. The ventral aorta and its branches are represented by shaded vessels; the systemic arteries as solid vessels. The left arm and leg have been omitted from the diagram, also a few of the smaller vessels described in the text, for the sake of clearness.

A. B.	Anastomosing branch between first and third efferent vessels.
A. B. I.	First afferent branchial artery.
A. B. II.	Second afferent branchial artery.
A. B. III.	Third afferent branchial artery.
Anas.	Anastomosing branch between intercostals and vertebral.
A. O.	Dorsal aorta.
Au.	Auditory.
Br.	Brachial.
Bs.	Basilar.
Ca.	Caudal Aorta.
C. C.	Cerebral carotid.
Coe. M.	Cœliaco—mesenteric.
Cor.	Coronary.
Cu.	Cutaneous.
C. V.	Trunk formed by the union of second and third efferent vessels.
E. B. I.	First efferent branchial artery.
E. B. II.	Second efferent branchial artery.
E. B. III.	Third efferent branchial artery.
E. B. A.	Branch to second afferent artery.
E. C.	External carotid.
E. I. M.	External inferior maxillary.
Epi.	Epigastric.
Fr.	Femoral.
G.	Gastric.
Gl.	Branch of caudal aorta to anal gland.
Hp.	Hepatic.
I. C.	Internal carotid.
I. Cls.	Intercostals.
I. I. M.	Internal inferior maxillary.
Il.	Iliac.
I. M.	Inferior mesenteries.
K.	Renal.
M.	Muscular branch of caudal aorta
O. N.	Orbito-nasal.
Oph.	Ophthalmic.
P.	Pulmonary.
P. b.	Muscular branch of pulmonary.
P. O. E.	Oesophageal branch of pulmonary.
P. S.	Muscular branch from pulmonary.
R. A.	Aortic root.
Sbc.	Subclavian.
Sp.	Splenic branch of gastric.
Sp′.	Splenic.
Sp. r.	Spermatics.
Tr.	Truncus arteriosus.
Vert.	Vertebral.
Vs.	Vesical.

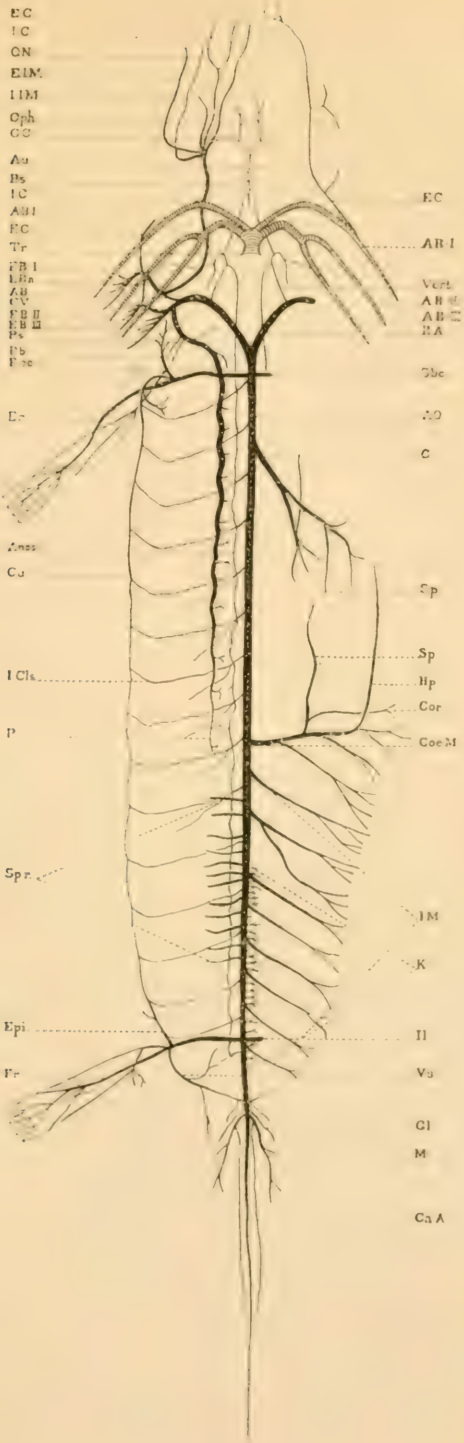
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PLATE 10.

Description of Plate 10.

Vascular System of *Necturus maculatus*.

Fig. 1. Afferent and efferent vessels on a larger scale than in Plate 9. The capillary connection between the two is omitted.

A. B.	Anastomosing branch between first and third efferent vessels.
A. B. I.	First afferent branchial artery.
A. B. II.	Second afferent branchial artery.
A. B. III.	Third afferent branchial artery.
A. O.	Dorsal aorta.
C. V.	Union of second and third efferent vessels.
E. B. I.	First efferent branchial artery.
E. B. II.	Second efferent branchial artery
E. B. III.	Third efferent branchial artery.
E. B. a.	Branch to second afferent artery.
E. C.	External carotid.
I. C.	Internal carotid.
P.	Pulmonary.
R. A.	Aortic root.
T. R.	Truncus arteriosus.

Fig. 2. Arteries of the arm and hand.

Br.	Brachial.
Br. a.	Branch to flexor carpi radials and first digit.
Br. b.	Branch to flexor carpi ulnaris and last digit.
C. a.	Branch of cutaneous to upper part of arm.
Cu.	Cutaneous.
Cu. a.	Branch of cutaneous to pectoral muscles.
T. A.	Thyroid axis.
T. a.	Muscular branch of Thyroid axis.
T. a. a.	Branch of T. a. to anconeus.
T. a. b.	Branch of T. a. to last digit.
T. a. c.	Branch of T. a. to first digit.
T. b.	Muscular branch to procoro humeralis, cucularis and antibrachialis.

Fig. 3. Arteries of the leg and foot.

C. A.	Branch to flexor tarsi tibialis and first digit.
C. B.	Branch to flexor tarsi fibularis and last digit.
Epi.	Epigastric.
Epi. B.	Branch of epigastric to body wall.
Epi. R.	Branch of epigastric to rectus femoris.
Fr.	Femoral.
Fr. a.	Muscular branch of femoral.
Fr. b.	Branch to last digit.
Fr. c.	Branch to flexor digitorum communis and first digit.
Il.	Iliac.
Vs. an.	Branch to cloaca.
Vs. c.	Vesical.
Vs. gl.	Branch to cloaca.
Vs. I.	Muscular branch.

fig 1

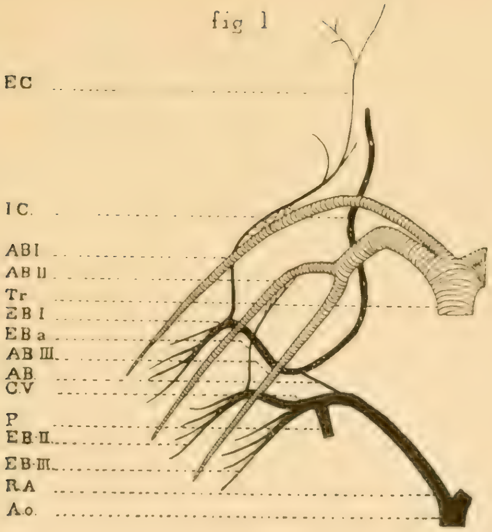

fig 2

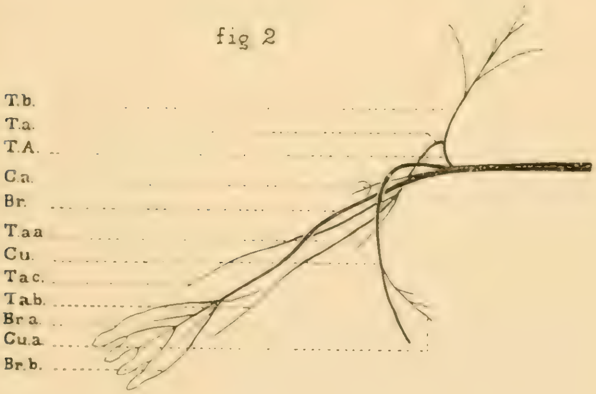

fig. 3.

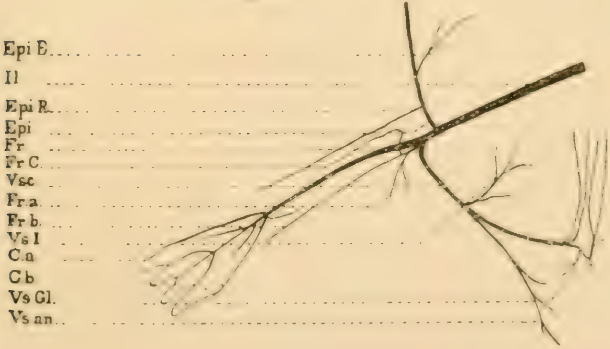

PLATE 11.

Description of Plate 11.

Vascular System of *Necturus maculatus*.....

The venous system of *Necturus maculatus*. The diagram is made from a ventral dissection. The liver has been turned over as far to the right as possible. The left arm and hand and the right leg and foot are shown. A few of the small veins and one of the large hepatic veins have been omitted for the sake of clearness.

A.	Anal.
Abd.	Abdominal.
C.	Caudal.
C. B.	Branch of caudal forming Renal Portal.
Cys.	Cystic.
D. C.	Duct of Cuvier.
F.	Fallopian.
Fbl.	Tibial.
G.	Branches from stomach to hepatic.
Gv.	Gastric.
H.	Hepatic.
H. P.	Hepatic Portal.
H. S.	Hepatic Sinus.
Hum.	Humeral.
Je.	External jugular.
Ji.	Internal jugular.
Js.	Jugular Sinus.
L.	Lateral.
Li.	Lingual.
Mes.	Mesenteric.
N. Or.	Naso-orbital.
O.	Ovarian.
P.	Pulmonary.
P. C.	Posterior cardinal.
Pel.	Pelvic.
Rdl.	Radial.
R. P.	Renal Portal; letters placed just above anastomosis with posterior cardinal.
Sbc.	Subclavian.
Sbm.	Submaxillary.
Sci.	Femoral.
Sp.	Splenic.
S. V.	Sinus Venosus.
V. Adv.	Venae advehentes.
V. Rev.	Venae reheventes.
W.	Ulnar.
Y.	Anastomosing branch between posterior cardinal and posteaval.
Z.	Branches from fallopian tube to posterior cardinal.

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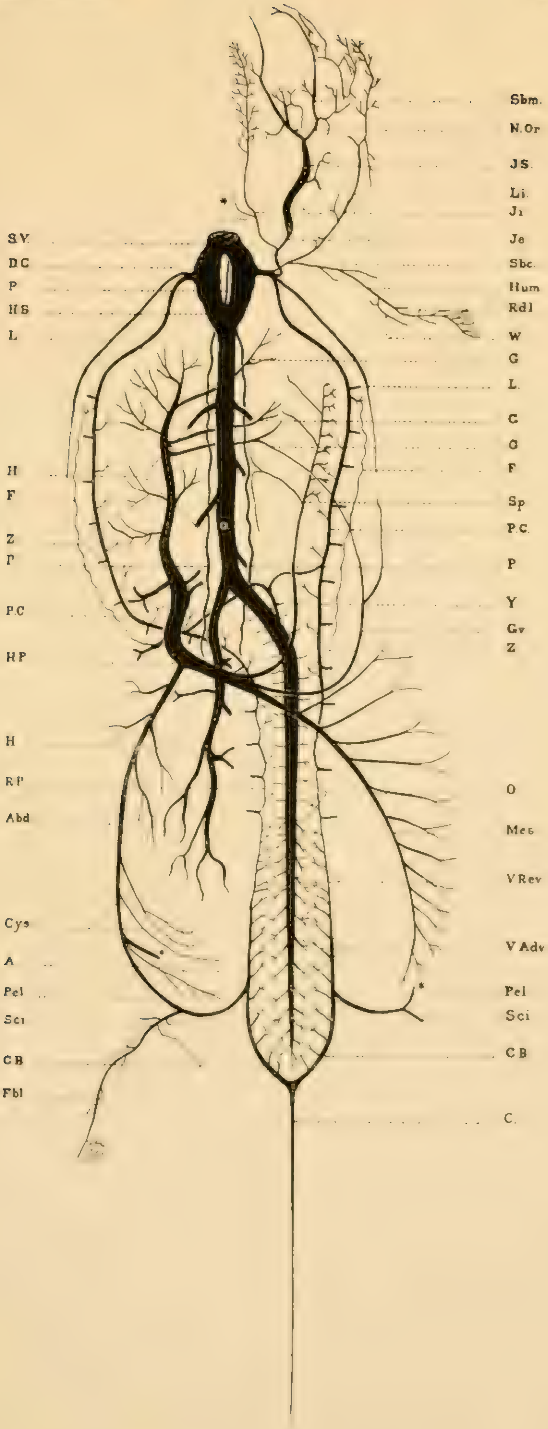
*The single star in the upper part of the diagram indicates the position of the pulmonary vein in the *Sinus Venosus*. The two stars in the lower part of the diagram indicate the cut pelvic vein, made necessary by the reflection to the right of the liver.


Sbm.
N.Or
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Je
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Y
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Gv
H.P
Z
H
R.P
O
Abd
Mes
V.Rev
Cys
V.Adv
A
Pel
Pel
Sci
Sci
C.B
C.B
Fbl
C.

THE BRAIN OF *Necturus maculatus.*

The brain of *Necturus* is long in proportion to its width and depth. Its greatest length, measuring from the superficial origin of the olfactory nerves to the beginning of the spinal cord is about 230 mm; its greatest breadth, measuring across the caudal part of the prosencephalon is about 50 mm; its greatest depth taken through the thalamencephalon at the origin of the pituitary body is about 22 mm.

Viewed from the dorsal side, Pl. 12, and enumerating from anterior to posterior we see that the brain is composed of the olfactory lobes which pass without any sharp line of demarcation into the hemispheres of the prosencephalon; back of the prosencephalon, as an undivided body, lie the thalamencephalon and mesencephalon and pineal gland; then, as a caudal continuation of the mesencephalon, we see the epencephalon which forms a rudimentary roof of the fourth ventricle; and finally sharply separated from the mesencephalon we can see the metencephalon or medulla oblongata.

In a ventral view, Pl. 13, we see the following parts: Lying farthest anteriorly are the olfactory lobes and cerebral hemispheres, then the thalamencephalon with its broad pituitary body which covers the mesencephalon except on the lateral sides, and finally we have the metencephalon.

In a lateral view we notice that the brain vesicles lie in front of one another and that there is but an insignificant departure from the straight and unflexed condition of the embryonic brain. This is true of most of the aquatic *Urodeles* as Fish has noted.

GROSS ANATOMY.

Prosencephalon. The prosencephalon is composed of two rounded cylindrical bodies which are sharply separated by a longitudinal fissure as far as the anterior closing plate. The cylindrical bodies are about 8.8 mm long and about 2.5 mm in diameter; they are slightly concave along their lateral border and straight along their median side, and at their posterior end they are more diverging than in front. Measured dorso-ventrally they are thickest at their posterior end and gradually narrow towards the origin of the olfactory nerve. In cross section their median surfaces are shown to be flattened while their outer are convex; the union of the two surfaces is marked by a sharp angle. As there is no sharp line of demarcation between the olfactory lobes and the hemispheres, for convenience of description they will be considered together; and thus each hemisphere is to be considered as composed of the olfactory lobe and the hemisphere proper.

On the other hand, in *Rana* and in the *Chelonia* the olfactory lobes can be readily distinguished from the cerebral hemispheres. In all these cases, however, the surface of the prosencephalon is perfectly smooth and is without convolutions.

Concerning the question as to whether the olfactory portion deserves setting apart as a separate segment there is at present a variance of opinion.

Steiner, working from a physiological standpoint, argues from experiments carried on in the shark, that the prosencephalon of every vertebrate has developed phylogenetically out of the olfactory organs.

Thalamencephalon and Mesencephalon. These two are united into a short cylindrical body with no sharp line of demarcation between them. This body is flattened or even slightly concave on the dorsal and ventral surfaces. These surfaces, with the exception of the median groove on the dorsal side, are all unbroken, there being no elevations or other external indications to mark the position of the optic lobes in the mesencephalon. In this respect the brain of the *Necturus* differs greatly from that of the *Dipnoans* on the one hand and from that of the *Rana* on the other. In both the latter cases we have the optic lobes well developed.

Anteriorly, it is sharply separated from the prosencephalon by a deep groove on the dorsal surface and a shallow one on the ventral; posteriorly, it is continued dorsally by the epencephalon or the cerebellum and ventrally by the metencephalon or the medulla oblongata. Measuring from the base of the pineal gland to the cerebellum it is about 5.8 mm long, and measured laterally it is about 3.1 mm in diameter. In cross section it will be noticed that the walls are very thick laterally, while dorsally they grow thinner until in the median line of the thalamencephalon there is only a thin layer of cells present. A cavity, the third ventricle and the Aqueduct of Sylvius, extends through the thalamencephalon and the mesencephalon and is of the same size throughout, except where the infundibulum joins it and anteriorly where it connects with the lateral ventricles of the cerebral hemispheres. At the place where the cavity of the infundibulum joins the thalamencephalon there is a V-shaped depression in the floor. At the anterior part of the cavity there is a gradual widening toward the foramen of Monroe. The relation of the pineal gland, pituitary body, optic and occulomotor nerves to these segments of the brain will be considered later.

Epencephalon. This is a short ledge which forms part of the roof of the fourth ventricle. It is thickest in its anterior part and thins out at the edges. Its general form is convexo-concave, when viewed from the dorsal side.

In the dorsal view of the brain, Pl. 12, it will be seen that the roof of the fourth ventricle extends further posteriorly than is indicated by Osborn. While he gives the roof as extending only as far as the superficial origin of the trigeminal, I found it extending further caudal, as far as the superficial origin of the facial.

Metencephalon. I consider the metencephalon as a direct posterior continuation of the ventral part of the mesencephalon, for in forms below the mammals we have no pons to mark a dividing line.

This is the longest part of the brain, being one and one-half times as long as the rest of the brain. The metencephalon extends from the mesencephalon in front to the first pair of spinal nerves and is of the triangular shape common in the lower vertebrates. From its rounded base at the mesencephalon it gradually narrows toward the spinal cord. On the dorsal surface, Pl. 12, we see a deep triangular fossa, the fourth ventricle, which is two-thirds the length of the metencephalon, its base being at the anterior part of the medulla and its apex being drawn out into a narrow fissure posteriorly. This cavity connects with the Aqueduct of Sylvius anteriorly. Besides the fossa on the dorsal surface there is a deep median groove which corresponds to the posterior septum, and on the ventral surface, one which corresponds to the anterior fissure of the cord.

The Pineal Gland. This is well developed in *Necturus* and extends forwards between the cerebral hemispheres to near their center, Pl. 12. It is a triangular-shaped body as seen in cross section, the apex being directed ventrad. Shortly after leaving the thalamencephalon it extends dorsally, becomes narrower, and its anterior end is applied against the roof of the brain case. Serial sections show, however, that it does not penetrate it.

Osborn, judging from his paper on the Amphibian brain, thinks that the pineal gland does penetrate the cranial roof. I have not found this to be the case in the specimens I have studied; it simply flattens against the roof. The gland is solid, containing no cavity.

The Pituitary Body. This arises from the postero-ventral part of the thalamencephalon and extends backwards 5 mm to near the origin of the VIIIth nerve, Pl. 13. After proceeding a short distance it narrows, but soon widens again, thus forming a slight enlargement at the posterior end, the hypophysis. The pituitary body lies on the floor of the brain case and conforms closely to its irregularities.

The pituitary body is hollow as far as the hypophysis. This cavity is oval in cross section and as it approaches the hypophysis gradually narrows dorso-ventrally until it is finally obliterated. The dorsal wall or roof of the infundibulum is very thin at the base of the pituitary body but increases in thickness as it proceeds posteriorly.

NERVES.

I. Olfactory. These are the most prominent pair of nerves. They arise directly from the ventro-lateral margin of the corresponding hemisphere. A sharp line on the dorsal side shows the place of origin of the nerve, but on the ventral side no sharp line of demarcation is present. On cross section the nerve is oval in shape.

In pursuing my work several peculiarities were noticed in the branching of the olfactory nerves of the brains studied. In one instance the nerve, a short distance from the olfactory lobe, broke up rapidly into branches, which ran some distance before entering the nasal capsule. This brain is the one used in the model and in the drawings. In another case the right olfactory nerve divided into two branches almost as soon as it left the lobe; but in most cases the nerve ran some distance before breaking up into its smaller branches.

II. Optic. This nerve is very small and fragile. It arises in the ventro-median line of the thalamencephalon just a little anterior to the posterior ends of the cerebral hemisphere. There are apparently no elevations or tracts at the place of origin of the optic nerve, but it seems to rise in conjunction with its fellow from the surface of the brain. The nerve runs obliquely from its place of origin, thus forming an acute angle with its fellow.

III. Oculo-motor. This nerve arises in the lateral median line at the extreme anterior part of the mesencephalon. It is very fragile and is nothing but a thread. It is very easily broken, often separating from the brain in dissecting away the meninges of the brain. It runs along the lateral surface of the brain until a short distance past the posterior ends of the cerebral hemisphere when it turns off obliquely to the muscles of the eye. It branches before reaching the ophthalmic branch of the 5th; the branches passing on either side of this nerve.

IV and VI. Pathetic and Abducent. I consider these two nerves together because there is a great variance of opinion as to their presence or absence in the various *Amphibia.*

Osborn in his discussions of the *Amphibian* brain claims to have found both of these nerves in the *Necturus,* though he fails to show the VIth in any of his drawings and to make any definite statement about either. In his drawings he gives the VIth nerve as arising from the roof of the 4th ventricle, at a point which corresponds to the cerebellum.

Fish failed to demonstrate the IVth in *Desmognathus.* Kingsley failed to find it in the larva *Amphiuma,* but Mrs. Gage found it in a very rudimentary condition in the adult *Diemyctylus.*

As to the VIth nerve Kingsley says it is not found in the larva *Amphiuma;* Osborn, as stated at the beginning of this topic, omits it from his figures; while Reissner and Ecker describe it in the Frog, and Fisher finds it in *Siredon* and *Necturus.* With these facts in view I retraced my work, studying carefully my serial sections and the many brains which had been dissected as well as those isolated by 20 per cent. nitric acid, and I have come to the conclusion that the IVth nerve is not present in *Necturus,* and if the VIth is, it has no separate origin. My reasons for this statement are the following:

1. In serial sections I was unable to find anything that corresponded to the IVth nerve at the place where Osborn gives its origin, i. e., in front of the cerebellum. Nor could I find anything which would correspond to the origin of the VIth.

2. Finding that by studying the brain alone I was unable to find the origin of these nerves in question, I decided to dissect out the muscles of the eye and see if from this I could trace the nerves. After a careful dissection in which as far as I could see the nerves remained intact I arrived at the following results: The muscles of the eye are supplied by the IIIrd and by branches of the Ophthalmic division of the Vth. All six muscles of the eye were supplied by these nerves as well

as other muscles adjoining. The Opthalmic nerve could be traced to the Gasserian ganglia as well as the branch in question, but I could not find, as already stated, a nerve arising from a separate origin that would correspond to the VIth, and there were no nerve fibres that could have arisen from the roof of the fourth ventricle.

V. Trigeminal. This is one of the largest of the cranial nerves. The trigeminal arises from the cephalo-lateral angle of the metencephalon. It runs forward at quite a sharp angle with the brain and just before it penetrates the brain case it joins the Gasserian ganglion from which two main branches pass out, the ophthalmic and maxillo-mandibularis.

VII. Facial. This arises in conjunction with and anterior to the VIIIth on a line parallel to the Vth and a short distance caudal. Near its origin it divides into two main branches, one of which joins the Gasserian ganglion, the other and larger continuing with the VIIIth nerve for a short distance and then separating.

VIII. Auditory. This is a thick and very short nerve, which shortly after separating from the VIIth divides into two main branches, which join the auditory vesicle. It extends out at right angles from the brain and, in its final branching, becomes like a brush.

IX. Glossopharyngeal. This arises by a single origin on a line parallel with the VIIth and a short distance posteriorly. It then proceeds caudal at a sharp angle with the brain for a short distance and unites with the Vagus.

X. Vagus. This arises from two separate origins about on a line with each other, and with the IXth at a place opposite the middle of the fourth ventricle. The posterior root is the smaller and unites with the anterior root just before the IXth joins them. The joint root thus formed runs into the ganglion of the Vagus.

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Plate 12.

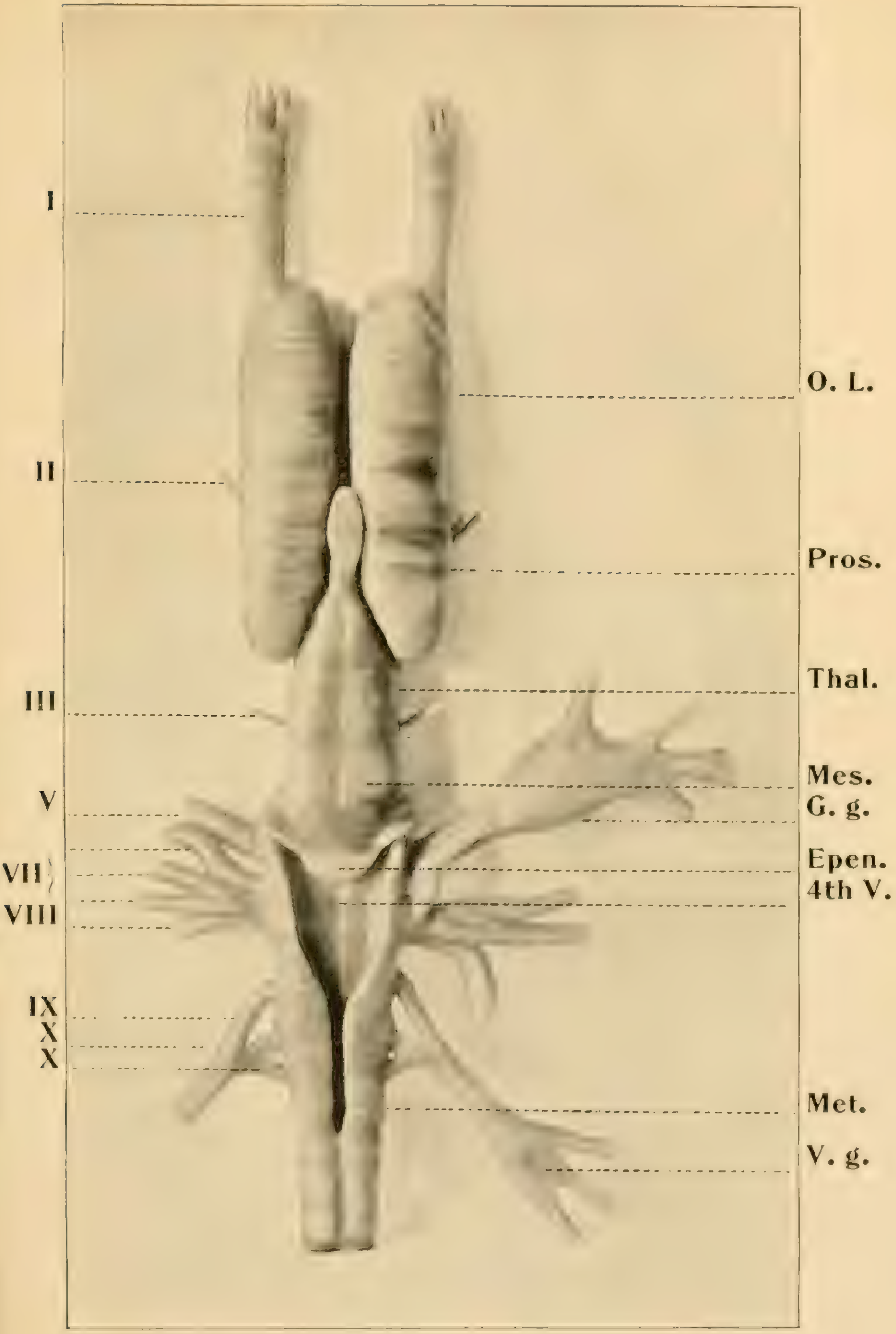
DESCRIPTION OF PLATE 12.

THE BRAIN OF *Necturus maculatus.*

Photograph of a model which was enlarged twenty diameters; in the plate it is reduced to about six and a quarter diameters. Dorsal view.

O. L.	**Olfactory Lobe.**
Pros.	**Prosencephalon.**
Thal.	**Thalamencephalon.**
Mes.	**Mesencephalon.**
Epen.	**Epencephalon.**
Met.	**Metencephalon.**
4th V.	**Fourth Ventricle.**
G. g.	**Gasserian Ganglion.**
V. g.	**Ganglion of the Vagus.**

I.	**Olfactory Nerve.**
II.	**Optic Nerve.**
III.	**Oculo-motor Nerve.**
V.	**Trigeminal Nerve.**
VII.	**Facial Nerve.**
VIII.	**Auditory Nerve.**
IX.	**Glossopharyngeal Nerve.**
X.	**Vagus Nerve.**


I
II
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IX
X
X
O. L.
Pros.
Thal.
Mes.
G. g.
Epen.
4th V.
Met.
V. g.

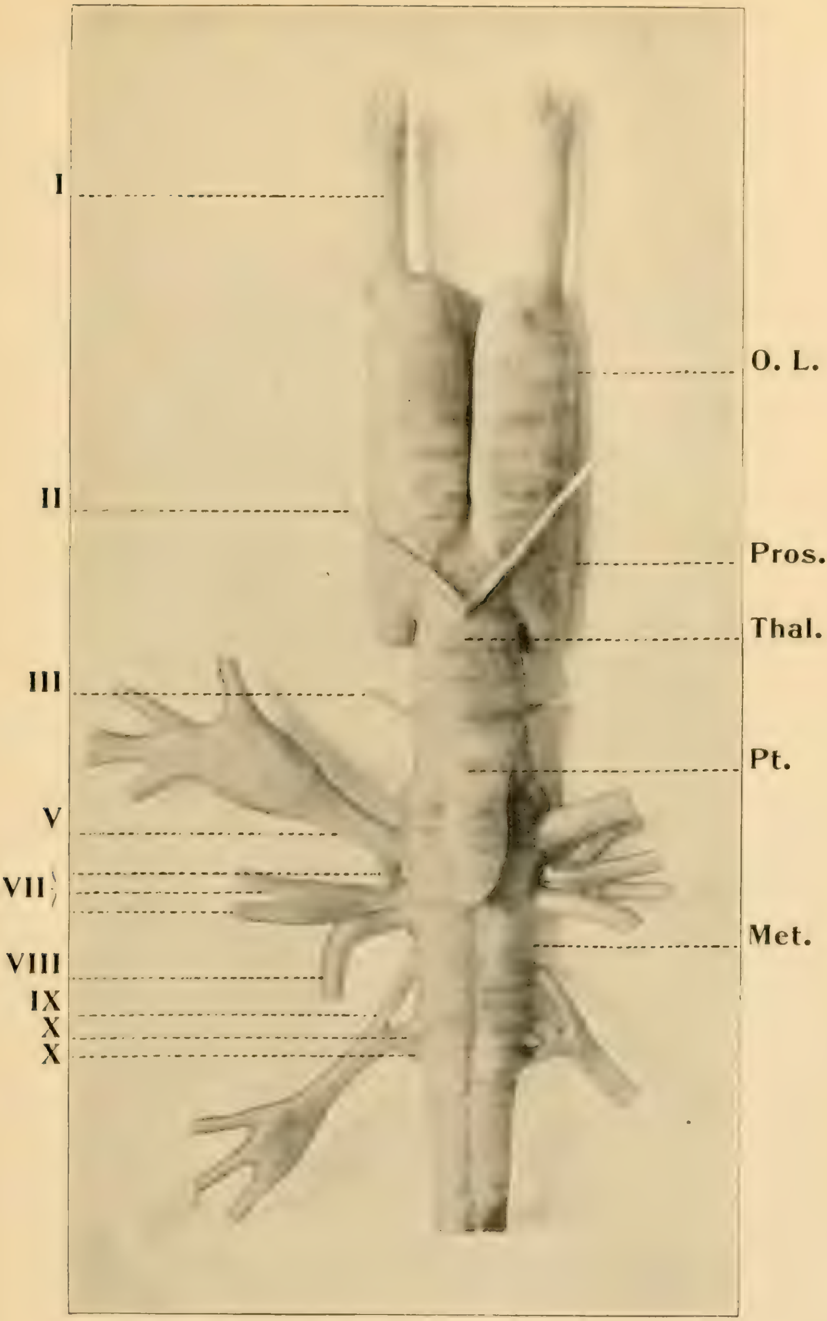
PLATE 13.

DESCRIPTION OF PLATE 13.

THE BRAIN OF *Necturus maculatus.*

Photograph of a model which was enlarged twenty diameters; in the plate it is reduced to about six and a quarter diameters. Ventral view.

O. L.	**Olfactory Lobe.**
Pros.	**Prosencephalon.**
Thal.	**Thalamencephalon.**
Pt.	**Pituitary Body.**
Met.	**Metencephalon.**
I.	**Olfactory Nerve.**
II.	**Optic Nerve.**
III.	**Oculo-motor.**
V.	**Trigeminal Nerve.**
VII.	**Facial Nerve.**
VIII.	**Auditory Nerve.**
IX.	**Glossopharyngeal Nerve.**
X.	**Vagus Nerve.**


I
II
III
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VII
VIII
IX
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X
O. L.
Pros.
Thal.
Pt.
Met.

THE EPITHELIUM OF THE PERITONEAL CAVITY OF THE CAT.

The cats used for the following study varied in age from six months up to two years. Each peritoneal cavity was examined with special reference to the epithelium of the central tendon, suspensory ligament of the liver, mesentery and great omentum. Each cat was chloroformed and bled thoroughly so as to lessen the possible chance of blood getting on the surfaces to be studied. The abdomen of the animal was then carefully opened and a piece of the omentum, of as large size as possible, was removed to the silver solution.

The remainder of the omentum was then turned aside, and a large fold of the mesentery, together with the intestine to which it was attached, was removed. The intestine was closed by means of a double ligature previous to removal, and if any blood-vessel appeared to contain a considerable amount of blood it was also ligated. The loop of intestine served as a convenient means of handling and protection from mechanical injury and was not removed until the staining was complete.

In some cases the peritoneal surfaces were stained in situ, to reduce the risk of injury to a minimum. In other cases the suspensory ligament and parts of the mesentery were removed by supporting them on a glass slide and carefully excising a portion with the scissors. The specimens were then transferred to the stain, while still on the slide, and floated off.

In all cases some one of the various solutions of nitrate of silver was used. A slight modification of Dekhuysen's method proved very satisfactory, giving sharp and clear boundary lines to the epithelial cells. In a few instances the nuclei were stained with haematoxylin.

Special effort was made to obtain as large pieces of the mesentery, omentum, etc., as possible. The great difficulty with such large specimens was that injury was so easily done to them, thus apparently detracting from their value. Important evidence, however, was furnished in this way as will appear later.

Nearly all the specimens of the mesentery were taken from that of the small intestine, because much greater delicacy in handling the material was possible here. Some preparations were made from the meso-colon; but as these were found similar in all respects to those from the mesentery of the small intestine, and as the danger of injury was much greater owing to its situation, most of the work was done on the mesentery of the small intestine.

The Peritoneal Epithelium. All of the epithelium of the peritoneal cavity which was studied consisted of a simple layer of flat, polygonal cells, bounded by rather relaxed, wavy lines. Pl. 14, fig. 1, 2, 3. The variation in the size and form of the individual cells in the same region of the peritoneal cavity was slight, but between different regions was quite noticeable. In general it may be said that the cells of the epithelium of the mesentery were the most uniform both in size and shape. They were larger than those of the central tendon and suspensory ligament, but smaller than those of the omentum. The cells of the latter were the largest and most irregular found; they were narrower in proportion to their length and were bounded by more undulatory and distinct lines.

The cells of the central tendon, suspensory ligament and diaphragm, although smaller than those of the omentum and mesentery, resemble them otherwise quite closely. Classified in the order of their size their order would be: diaphragm, suspensory ligament, central tendon, mesentery, omentum,—the latter being the largest. If the straightness of the intercellular lines is taken as a basis the order would be: diaphragm, central tendon, mesentery, suspensory ligament, omentum,—the latter having the most wavy lines. This classification has little significance, however, for as Schwartz (20) and Muscatello (14)

NOTE.—In this paper reference to the literature is made by means of number inclosed in ( ). The titles of the papers or books referred to will be found in the Bibliography, page 245.

have shown, the shape of the cells and the condition of relaxation of their bounding lines is dependent on tension.

With the increase in age of preparation the appearance of the epithelium was found to change. Numerous granulations appeared and the nuclei were seen in clear relief. The stronger the solution of nitrate of silver used the larger and more numerous were the granules.

Owing to these phenomena it was found advisable to study all preparations immediately after they had been mounted. In preparations which had been impregnated with a weak solution of nitrate of silver (2:1000) these granules were usually absent even after being kept for some months. In some specimens numerous cast-off epithelial cells were found, but in no case was anything at all comparable to Klein's "germinating cells" found.

Stomata. Klein (7) accepts the conclusions of v. Recklinghausen (19) which he says were reiterated by Ludwig and Schweigger-Seidel (13), Dybkowsky (4), Schweigger-Seidel and Dogiel (21), and Böhm (3). Klein himself declares that "we can only consider those figures as stomata which lie in the center of radially disposed, relatively large endothelial cells." "All other indications," he continues, "are very probably only young cells formed by division of the larger." He also admits that it is a difficult question to decide whether certain structures can be called stomata or not.

Ellenberger (5) practically agrees with this view, adding that "these numerous stomata are bounded by the free ends of the imbedded nuclei." Ranvier (17), on the contrary, denies the existence of stomata and regards these structures as nothing else than "small inter-endothelial spots." Arnold (1), in his earlier writings speaks of stomata and stigmata; but in his later, he declares that "stigmata are nothing else than scattered diffusions of the fluid or semi-fluid inter-cellular substance."

Klein in a later publication than the one mentioned above (8) and especially in his joint publication with Noble Smith (9) goes much farther than any of the previous investigators, not only as to the classification of stomata, but also regarding the importance which he ascribes to them. They divide stomata into *stomata vera* and *pseudo-stomata.* Stomata vera are small openings at the junction of several epithelial cells. They are said to be bounded by small cells in the process of division—the so-called "germinating cells." "These cells when ripe become detached and may at once be absorbed as lymph corpuscles" (*sic*).

The character of pseudo-stomata they describe as follows:

> "There exist superficial branched cells in the serous membranes which lie either totally or partially between the endothelium of the surface, or, as is more commonly the case, only reach the surface by a process which projects between the superficial endothelium. * * * * We shall show * * * what great importance must be ascribed to these freely projecting cell processes; we call them pseudo-stomata."

These cell processes by budding give rise to single cells, and in certain pathological conditions cell proliferation takes place from them. Klein also makes the statement that "in female frogs, during the spawning season, the endothelial cells lining the stomata are ciliated"; a statement which I can not support and have not found corroborated by anyone.

Although the subject has received much attention from investigators there still exists a great diversity of opinion as to what are, and what are not, stomata; or, to put it differently, what are pre-formed natural openings and what are artificial. Even those authors who express a belief in the existence of stomata do not do so in an unqualified manner.

In general, stomata may be designated as small gaps or openings in the intercellular substance of serous membranes. Some investigators assert that these openings are pre—others that they are post—embryonic formations; while still others maintain that they are accidental.

One obstacle in the way of some definite conclusion is the fact that investigations have been made on different animals, or at least different parts of the same animal, under different conditions, by different methods, and with conflicting results. Another obstacle is that some investigations have been carried on to prove a preconceived idea and authors have read into every point evidence in support of their idea without viewing the subject in an impartial manner.

The frog seems to have been especially studied, although the toad, rabbit and Guinea-pig have frequently been used. The membranes which have been most studied and where stomata have been most frequently described are the diaphragm of the rabbit and the mesentery of the frog. In a few instances the cat, mouse, dog, and in one case man, has been made the subject of investigation. The central tendon of the diaphragm has also been an object of special study, but the investigators fail to agree; the same may be said of studies of other serous membranes. Yet in spite of these facts we are told "that stomata are found with certainty in the serous membranes of all small animals" (Krause).

The methods of investigation may be classified as follows, viz., 1, absorption; 2, injection; 3, impregnation.

Absorption. This method depends upon the penetration of solutions into the superficial lymphatics and was formerly much used. Milk, blood, etc., were placed in contact with the central tendon of the diaphragm and after a little most of the fluid would be absorbed. Colored fluids, such as a solution of Berlin blue, or fluids holding fine granules in suspension, as carmine or Chinese ink, have been used. They were either introduced into the body cavity or merely brought in contact with the diaphragm by allowing them to drop on its peritoneal surface. Artificial respiration has also been used to promote absorption; it being claimed that it had a direct influence—acting as a pump (Ludwig).

Injection. This may be done either by the "puncture method" or by inserting a fine canula directly into a lymph-vessel. Dybkowsky (4) claimed that by injecting the lymphatics it could be shown that the superficial lymphatics of the intercostal pleura lead freely between the endothelium of the surface by short vertical branches. Schweigger-Seidel and Dogiel (21) conclude from an injection of the *cysterna lymphatica magna* of the frog that the body cavity was in open communication with the former by means of circular openings—stomata.

Impregnation. This consists in treating the serous membranes with some stain, generally nitrate of silver, which will bring out the cell boundaries. Most of the later investigations have been carried on by this method and it is the one I have used exclusively.

Facts obtained by the first two methods, and to some extent by the last, have lead many authors to assert that the irregular distributed figures found between endothelial cells are stomata. That such figures occur can not be denied; but are they necessarily natural pre-formed openings? Or, granting that stomata are present in the frog, does it necessarily follow that they are present in mammals, which present a higher and more complex structure?

Significance of Stomata. Here again, as on the whole question of stomata, the greatest diversity of opinions exists. The greater number of the investigators who have expressed any opinion in this matter, regard stomata as free openings affording passage to the superficial lymphatics. Ludwig, Schweigger-Seidel, Klein, Rawitz, and others, speak of the passage of leucocytes through these openings, and Ellenberger (5) adds that they are sometimes plugged up with lymph cells. After referring to the work of Schweigger-Seidel and Ranvier, Ellenberger says: "These (the gaps in the intercellular substance) lead directly into the lymph-spaces."

Ranvier (17), however, did not hold this opinion, for he says:

> "Most histologists consider the small inter-endothelial spots as pre-existing stomata designed for the free passage of the lymph cells; * * * but the irregular distribution of these spots and their absence if, previous to the employment of silver nitrate, the almuminate covering the surface has been removed, argues against the presence of pre-existing openings. The presence of these spots upon the omentum which is already so largely perforăted, and where the passage of white corpuscles is perfectly unnecessary, adds a further argument against the opinion of those who would call these structures stomata."

In his chapter on the structure of the capillaries Ranvier expresses himself as strongly opposed to the presence of the stomata and stigmata described by Arnold; and, after referring to the experiments of Cohnheim, says:

> "The number of stomata seem consequently to depend on the number of blood corpuscles which have passed through the walls of the vessel, and this observation suggests the thought, contrary to the conclusions of Arnold, that the stomata are not preformed but that they are produced within the capillaries by the passage of corpuscles."

Although Arnold (1) accepts the existance of stomata, he does not believe in their open communication with the lymphatic system. Rawitz (18) assumes the passage of leucocytes, but does not seem to be able to convince himself that there are free openings; he suggests that there are "at least soft places."

Tourneaux (23) believes the so-called stomata are artifacts, and says that he did not succeed in verifying a connection between the body cavity and the lymph-spaces. His conclusions were based upon experiments with starch and carmine granules, neither of which, he asserts, will penetrate into the lymph-vessels when introduced into the body cavity. He concludes by saying that the lymph cavity can be filled and the body cavity remain empty, or *vice versa,* without the passage of the starch or carmine from the one to the other.

The conclusions of Tourneaux are of special interest because they directly contradict the views given above; for most of the authors mentioned, base their opinions upon the statement that when solutions holding starch or colored granules in suspension are injected into the abdominal cavity, the granules will after some hours be found in the superficial lymph-vessels.

Muscatello (15) maintains that the central tendon of the diaphragm is the only place where stomata may be found, and even here they are somewhat doubtful. From the standpoint of absorption and diapedesis it is difficult, indeed, to see why stomata should be necessary to absorption in one region of a serous cavity and not in another. If leucocytes can pass through the walls of the blood and lymph-vessels without the presence of stomata, it does not seem a good argument to say that they are necessary elsewhere; besides if stomata are a *sine qua non* to absorption they certainly ought to be found in the intestine.

RESULTS.

The great difficulty in the preparation of all my material was the danger of mechanical injury during the removal of the specimens from the animals, during the staining, and even in mounting. As large pieces as possible were used, some measuring 20×30 mm. The difficulty in obtaining large specimens was the presence of blood-vessels and fat; these prevented the use of high powers by not allowing the cover-glass to lie close to the specimen throughout its entire extent. By the exercise of great care specimens of the above mentioned size could be obtained which showed no discontinuities, each epithelial cell being bounded by sharp, continuous lines.

The distribution of such openings or discontinuities as I was able to demonstrate in the epithelium of the peritoneal cavity of the cat was extremely irregular. Their size and shape was substantially alike on the central tendon of the diaphragm, the mesentery, omentum, suspensory ligament and the peritoneal surface of the diaphragm.

No specimens were obtained where the occurrence of these discontinuities obeyed any general rule or law. For, while specimen "A" from the suspensory ligament might have less than specimen "A" from the mesentery, specimen "B" from the former might have more than "B" from the latter. Their distribution was found to be an entirely arbitrary one with respect to the different regions of the peritoneal cavity. When present the greater majority of these figures were found at the junction of inter-cellular lines, Pl. 14, fig. 4. If, however, discontinuities were present in very large numbers, they were also found in individual lines as well as at their intersection.

All manner of variations as to size and shape were found. While in some parts of a given specimen they were more or less circular in shape and located at the junction of several intercellular lines, in other parts of the same specimen they would be arranged in chains of various sizes, but usually larger structures, which in some instances nearly equaled the adjacent cells in size, Pl. 14, fig. 6. In some specimens one or more nearly circular openings were seen at the center of four or five radially disposed cells, Pl. 15, figs. 7, 8, 9. At first they were thought to be examples of openings plugged by lymph-corpuscles, as mentioned by Ellenberger, but a careful study of such specimens stained with nitrate of silver alone or in combination with nuclear stains showed that such was not the case. In addition to these forms still others, usually smaller than the above and more uniform in size and shape, were found. These instead of resembling small openings had the appearance of dots; they were often located at the intersection of intercellular lines or on the cells themselves, Pl. 14, fig. 5.

Closely allied to these, but less frequent in occurrence and of much greater significance, were small circular figures situated at the intersection of intercellular lines. The peculiarity of these figures was that the cell boundaries were visible either above or beneath them, and could, by careful focusing, be traced to a point of intersection.* These undoubtedly represent cases in which, owing to a slight injury, the albuminous material in the cement substance exuded in insufficient quantity to entirely obscure the underlying boundary lines; or, owing to the same cause, the silver solution penetrated beneath the epithelial cells, giving rise to a slight diffusion, Pl. 15, fig. 10.

All figures which resembled mere discontinuities or clefts were usually quite distinct and were bounded by lines very similar to the intercellular lines themselves. The more symmetrical figures were largely outnumbered by the irregular ones. This irregularity was not only one of size and shape, but also of distribution.

Stretching of a membrane at the time of its removal had the effect of producing discontinuities along the intercellular lines, Pl. 15, fig. 11. Schwartz (20) and Muscatello (14) have shown that the differences in form of endothelial cells are dependent upon the degree of contraction or distention of the organs which they line; or in other words, that the shape of the cells is dependent upon the degree of expansion of the epithelial membrane.

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*The study of these figures is greatly facilitated by the use of Abbe's stereoscopic eye-piece made by Zeiss of Jena.

In the case of stretched membranes the tension has been increased to a point where the cells have been torn asunder. The cement substance, albuminous in character, has exuded and given rise to dots or circular figures when exposed to the silver stain, while larger ruptures appear as various-sized and shaped openings between the cells.

Mechanical force, when applied to freshly mounted specimens in Canada balsam, would often cause separation of the cells. To show the effect of mechanical force specimens which showed, when first mounted in balsam, no openings, were subjected to various degrees of pressure. A certain relation between the distribution and number of the resultant interruptions and the force with which the cover-glasses were weighted was found to exist. The greater the weight the more numerous the openings, and if the pressure was applied to any particular part of a cover-glass a change in the shape of the cells would follow. This was manifested by a straightening of the intercellular lines and the appearance of numerous openings between the cells which radiated more or less from the center where the weight was applied.

When the epithelium was underlaid by adipose tissue, blood-vessels or Pacinian corpuscles, or in other words, when the epithelium was supported by an elastic pad, separation of the cells did not take place.

CONCLUSIONS.

As the result of my investigations I am forced to conclude that in the central tendon, suspensory ligament, omentum and mesentery of the cat there are no pre-formed natural openings commonly called stigmata and stomata.

It is true that I frequently obtained figures which corresponded with the usual description of these structures; but, owing to their great irregularity of distribution, their equally great diversity in size and shape, together with their mechanical production, I am led to regard them as accidental formations.

Indeed, my investigations have convinced me that the presence of these figures is a purely accidental and arbitrary one, due to imperfect (possibly unavoidably so) methods of preparation.

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PLATE 14.

DESCRIPTION OF PLATE 14.

PERITONEAL EPITHELUM OF THE CAT.

Fig. 1. Epithelium from the omentum.

Fig. 2. Epithelium from the suspensory ligament.

Fig. 3. Epithelium from the mesentery.

Fig. 4. Epithelium from the mesentery, showing that the location of the majority of the discontinuities is at the intersection of the intercellular lines. A few dots are seen which, if situated on intercellular lines, would be called stigmata.

Fig. 5. Epithelium from the suspensory ligament. Note the small figures of regular outline; some situated on the intercellular lines, others on the cells themselves. The only difference between them is their situation; if they are to be called stigmata in one situation, why not in the other?

Fig. 6. Epithelium from the mesentery. This preparation shows the widely divergent character of the intercellular discontinuities.

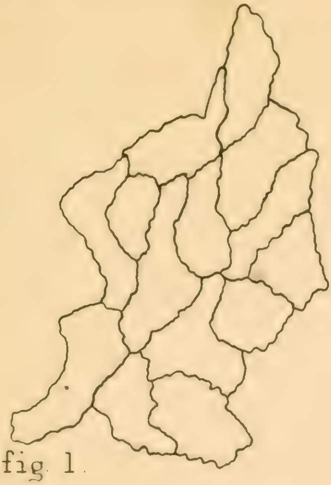


fig. 1.

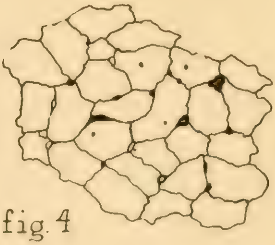
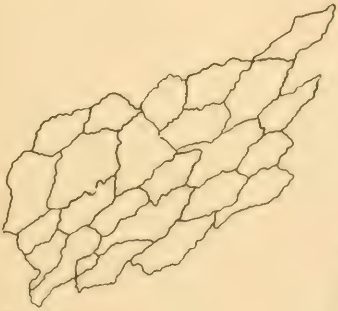


fig. 4



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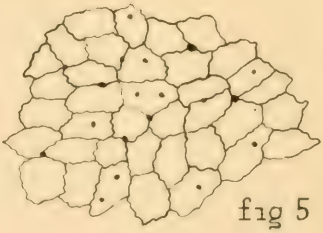

fig 5

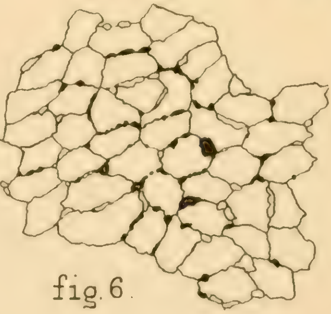

fig. 6.

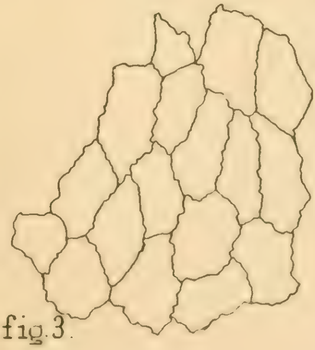

fig. 3.

PLATE 15.

DESCRIPTION OF PLATE 15.

PERITONEAL EPITHELUM OF THE CAT.

Figs. 7, 8, and 9. Three preparations from the mesentery. These figures are of great interest because they show how easily one might mistake the opening in the first for a stomata and in the last two figures it would be possible to say that they were small cells filling up the opening of the stomata. Their position corresponds to that assigned to stomata by Klein, i. e., "in the center of radially arranged, relatively large endothelial cells."

Fig. 10. From the mesentery. Note especially the figure which is shown more highly magnified at the left. As viewed under a low power the point indicated appears as one of the so-called stigmata, but when viewed under a higher amplification, especially if an Abbe stereoscpic eye-piece is used, it is easily seen that the dark spot is *under* the epithelial cells and that the cell boundaries are intact.

Fig. 11. From the mesentery. This figure shows the same appearance as figure 6, and also illustrates the effect of stretching.

Figs. 1–10 from the Cat; fig. 11 from the Frog. All figures were drawn under the camera lucida.

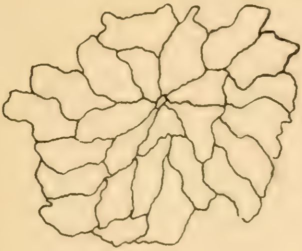

fig. 7

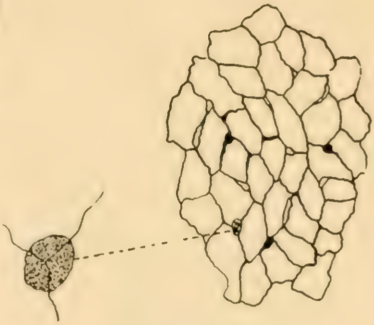

fig. 10

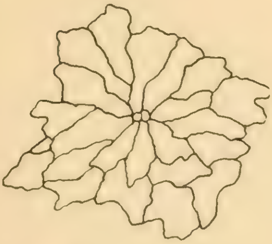

fig. 8.

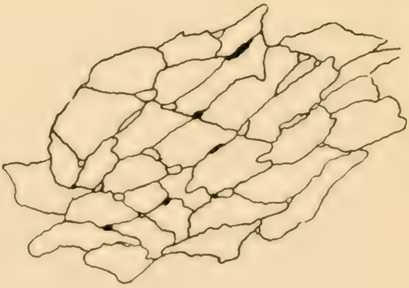

fig. 11

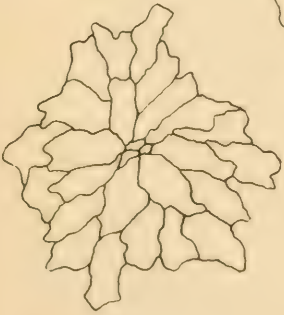

fig. 9

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